Integrated approaches to health

A handbook for the evaluation of One Health

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Network for Evaluation of One Health

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EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Wageningen Academic Publishers

Chapter 3

A One Health evaluation framework

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Abstract

Challenges calling for integrated approaches to health, such as the One Health (OH) approach, typically arise from the intertwined spheres of humans and animals, and the ecosystems constituting their environment. Initiatives addressing such wicked problems commonly consist of complex structures and dynamics. The Network for Evaluation of One Health (NEOH) proposes an evaluation framework anchored in systems theory to address the intrinsic complexity of OH initiatives and regards them as subsystems of the context within which they operate. Typically, they intend to influence a system with a view to improve human, animal, and environmental health. The NEOH evaluation framework consists of four overarching elements, namely: (1) the definition of the OH initiative and its context; (2) the description of its theory of change with an assessment of expected and unexpected outcomes; (3) the process evaluation of operational and supporting infrastructures (the 'OH-ness'); and (4) an assessment of the association(s) between the process evaluation and the outcomes produced. It relies on a mixed-methods approach by combining a descriptive and qualitative assessment with a semi-quantitative scoring for the evaluation of the degree and structural balance of 'OH-ness' (summarised in an OH-index and OH-ratio, respectively) and conventional metrics for different outcomes in a multi-criteria-decision analysis. We provide the methodology for all elements, including ready-to-use Microsoft Excel spread-sheets for the assessment of the 'OH-ness' (Element 3) and further helpful worksheets as electronic supplements. Element 4 connects the results from the assessment of the 'OH-ness' to the methods and metrics described in Chapters 4 to 6 in this handbook. Finally, we offer some guidance on how to produce recommendations based on the results. The presented approach helps researchers, practitioners, policy makers and evaluators to conceptualise and conduct evaluations of integrated approaches to health and enables comparison and learning across different OH activities, thereby facilitating decisions on strategy and resource allocation. Examples of the application of this framework have been described in eight case studies, published in a dedicated Frontiers Research Topic (https://www.frontiersin.org/research-topics/5479).

Keywords: One Health, transdisciplinary, integrated approaches to health, evaluation framework, theory of change

3.1 Introduction

Many current health challenges, such as spread of zoonotic infectious diseases, environmental pollutants, antimicrobial resistance, climate or market-driven food system changes with consequences on food and feed supplies, malnutrition including obesity and many more arise from the intertwined spheres of humans, animals and the ecosystems constituting their environment (FAO, 2013; Jones *et al.*, 2008). They are recognised to be wicked problems and need to be tackled using integrated approaches to health (Pfeiffer, 2014; Romanelli *et al.*, 2015; Whitmee *et al.*, 2015). Here, we conceptualise integration as inter- or transdisciplinary approaches. Such approaches consider the needs, values and opinions of multiple disciplines, sectors and stakeholders. They also bring together the scientific and

non-scientific communities, influencing, or influenced by, the challenge and their combined know-how and resources (Rüegg *et al.*, 2017; Stokols *et al.*, 2013; Zinsstag *et al.*, 2011). Due to the existing, historically contingent, separation of sectors and disciplines, developing integrated approaches is difficult and the realisation of benefits can be delayed. There is a need to provide evidence on the added value of these integrated and transdisciplinary approaches to governments, researchers, funding bodies, and stakeholders (Ledford, 2015; Rabinowitz *et al.*, 2013; Stokols *et al.*, 2003).

The NEOH evaluation framework uses a systems approach and regards the context of a OH initiative as the system within which it operates, and the initiative itself as a subsystem, which has a potential to affect the system to a smaller or larger degree. Drivers, operations, supporting infrastructure and outcomes were identified as fundamental characteristics of OH initiatives (Rüegg *et al.*, 2017). The NEOH evaluation framework relates the aspects of operations (i.e. OH thinking, OH planning and OH working) and supporting infrastructure (i.e. systemic organisation, learning and sharing) summarised as OH process characteristics ('One Health-ness'), to changes and outcomes evoked by a specific initiative. This is an important step towards identifying added value arising from integration across disciplines and sectors (i.e. transdisciplinarity). Figure 3.1 illustrates the relations between drivers, operations, supporting infrastructure and outcomes of OH and how the system evolves when a OH approach is engaged (Rüegg *et al.*, 2017).

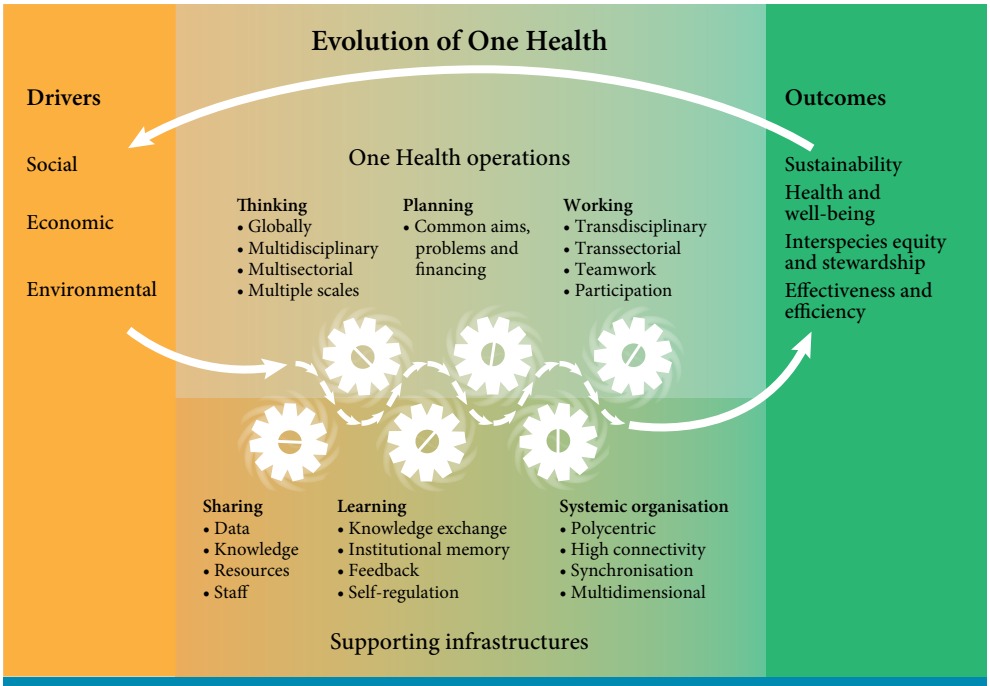

Figure 3.1. One Health characteristics identified during a workshop held in Cluj, Romania, June 2015, by members of the COST Action TD1404: Network for Evaluation of One Health. Published in Rüegg *et al.* (2017).

In brief, drivers refer to a collective perception of multiple and complex origins behind health problems, such as social (Commission on Social Determinants of Health, 2008) and environmental determinants of health (Lang and Rayner, 2012), as well as economic drivers (Woodward *et al.*, 2001). Social drivers include lack of participation or well-being, as well as the presence of ignorance, poverty, poor governance, mental and physical illness, or high risks for these. Environmental drivers include climate change, land degradation, and other ecosystem changes rooted in both natural phenomena as well as human actions. Economic drivers are mostly related to the globalisation process, dominated by market deregulation and financial capital, and largely irrespective of social needs at the local level (Rayner and Lang, 2012; Woodward *et al.*, 2001). These examples are by no means exhaustive and there is clearly an interplay between different drivers. For example, increased poverty in conjunction with close contact to previously unexploited environments puts human and animal health at risk (Pfeiffer, 2014). Similarly, economic crises and financial deregulation reduce public resources for interventions, reinforcing negative environmental, economic and social drivers, and exacerbating negative health outcomes (Khanal and Bhattarai, 2016).

As a response to these drivers, OH initiatives can range from development projects to educational programmes, research projects and inter-governmental strategies. Although disparate, these initiatives often have specific operating principles, characterised by a way of thinking, planning and working. 'OH thinking' is holistic, inclusive, respectful and tolerant, as opposed to approaches that are specific, reductionist, with a tendency to focus on single or limited outcomes that impact positively on few people only. It considers multiple scales (levels) of life, disciplines, sectors, species, paradigms and demographics, and integrates at different spatial scales (e.g. locally, nationally and globally). This should reflect the connected nature of social relations and social systems, both in their material and symbolic dimensions as well as the degradation of national resources due to globalisation (Wolf, 2015). 'OH planning' requires that aims, problem formulation, responsibilities and financing are organised regardless of organisational hierarchies, paradigms, sectors and disciplines. Finally, 'OH working' relies on a transdisciplinary approach bridging knowledge between disciplines, sectors, the scientific and non-scientific communities, and actively includes stakeholders in the process, from problem definition to resolution. To operate as conceived, OH must rely on adequate information infrastructure and foster learning across all scales and fields (Ciborra and Hanseth, 1998). An OH learning framework allows for stakeholders and institutions to evolve and improve autonomously, and requires mechanisms for knowledge exchange, institutional memory, feedback and regulation. This relies on sharing of knowledge, data, resources and staff across sectors and disciplines. This working paradigm will often lead to complex, poly-centric organisational structures that support development towards sustainability and resilience (Retief *et al.*, 2016).

The expected outcomes of OH initiatives are health and welfare of humans, animals, plants and ecosystems, all managed by common health strategies. This ensures healthy food, as well as clean water and air. Transdisciplinarity should result in improved stewardship and compliance, and promote interspecies equity, which would facilitate sustainable benefits for humans from other species (domestic and wild) and their habitats. Furthermore, OH should improve effectiveness across different sectors and at multiple scales. It relies on and results in more efficient communication, thereby generating a higher degree of awareness that can

enable rapid detection of illness and consequent action. By having a more inclusive voice for neglected human populations, animals and ecosystems, OH is intended to widen our usual anthropocentric perspectives, and to simultaneously enhance human health. The expected outcomes of OH approaches contribute to the three pillars of sustainability, namely society, environment and economy.

3.2 Evaluation framework and steps

Figure 3.2 provides an overview of the NEOH evaluation framework. There are four overarching Elements in the evaluation process:

- Element 1: defining and describing the OH initiative and its context (i.e. the system, its boundaries, and the OH initiative as a subsystem), providing information for the further Elements.
- Element 2: assessing expected outcomes based on the theory of change (TOC) of the initiative, and collecting unexpected outcomes emerging in the context of the initiative.
- Element 3: assessing the 'One Health-ness', i.e. the implementation of operations and infrastructure contributing to the OH initiative.
- Element 4: comparing the degree of 'One Health-ness' and the outcomes produced.

The framework relies on a mixed methods approach that combines a descriptive and qualitative assessment with a semi-quantitative evaluation (scoring) for the evaluation of the 'One Health-ness' with a OH-index, while including conventional metrics for outcomes in a multi-criteria-decision-analysis.

The following chapters translate the schematic into distinct steps to be considered from defining the system to characterising the OH initiative to elaborating a TOC to identifying and selecting the evaluation type and metrics for outcomes.

The framework can be used for external or self-evaluation. It is recommended that the evaluator is comfortable with systems thinking (Trochim *et al.*, 2006; Whitehead *et al.*, 2015) to approach the complex structures and dynamics of OH initiatives and their context. Data and information can be gathered from actors and stakeholders using methods such as open or semi-structured interviews, focus group discussions or other qualitative data collection approaches, from resources used or produced by the initiative (Garcia and Zazueta, 2015), and related (external) primary or secondary datasets.

For examples that apply the method presented here, the readers can refer to the case studies included in the Frontiers research topic 'Concepts and experiences in framing, integration and evaluation of One Health and EcoHealth' (https://www.frontiersin.org/research-topics/5479). Paternoster and co-workers evaluated integrated surveillance of West-Nile virus (Paternoster *et al.*, 2017), Radeski and co-authors applied the framework to an animal welfare centre (Radeski *et al.*, 2018), Léger and co-workers evaluated a research project on antimicrobial resistance involving four faculties, the industry and health authorities (Léger *et al.*, in press), Buttigieg and collaborators compared control strategies for brucellosis in Serbia and Malta

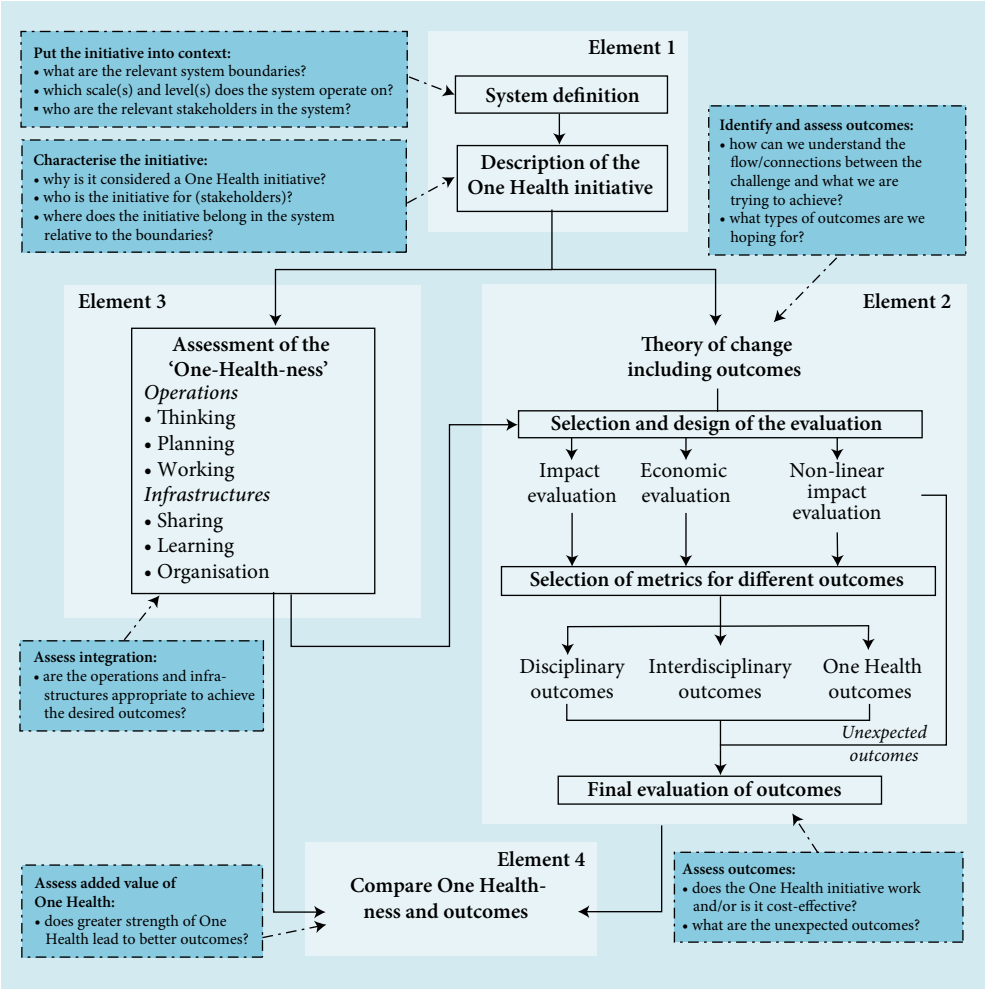

Figure 3.2. Flow chart of elements to be considered during a One Health evaluation (in grey) with their purpose and the associated questions to be answered (blue boxes). In Element 1, the initiative and its context are described to inform Element 2 and 3. Element 2 relies on a Theory of Change to identify expected outcomes and collects unexpected outcomes through non-linear impact assessment. In Element 3 the implementation of operations and infrastructure contributing to the One Health initiative is assessed. The two assessments are compared in Element 4. Published in Rüegg *et al.* (2018).

(Buttigieg *et al.*, 2018), Muñoz-Prieto and co-workers assessed a study on factors affecting obesity in dogs and dog-owners (Muñoz-Prieto *et al.*, 2018), Laing and collaborators evaluated a project mitigating the effects of the unexpected domestic re-use of containers employed for organophosphates in a tick control programme (Laing *et al.*, 2018), Fonseca and co-authors applied the framework to evaluate a cross-sectoral observatory of taeniasis and cysticercosis

(Fonseca *et al.*, 2018), and finally Hanin and collaborators evaluated an international and inter-sectoral centre for infectious disease surveillance (Hanin *et al.*, 2018).

3.3 Element 1: definition of the OH initiative and its context

Element 1 of the evaluation framework (Figure 3.2) consists of a general overview (Section 3.3.1), a visual representation and a textual description of the system in which the initiative operates (Section 3.3.2), and an analogous illustration and description of the initiative within this context (Section 3.3.3). They do not need to be developed in sequence, but may evolve iteratively, and may be developed by a group of evaluators, by the stakeholders of the initiative, or by these two groups in collaboration.

Before designing an evaluation, the evaluation question(s) must be clearly stated. To answer these questions and to select an adequate evaluation design, it is important to gain a principle understanding and overview of the activities to be evaluated (Williams, 2016). The framework presented here uses a systems approach and regards the context of an OH initiative as the system within which it operates, and the initiative itself as a subsystem conceived to induce change in this context. Systems have been defined in many different disciplines and frameworks e.g. (Anderson and Johnson, 1997; Ifejika Speranza *et al.*, 2014; Meadows, 2008; Whitehead *et al.*, 2015; WHO, 2009). A fundamental feature is that systems are composed of a set of interacting or interdependent components that form a complex whole (Anderson and Johnson, 1997). This implies a hierarchical organisation and a concept of levels or scales within different dimensions (Pumain *et al.*, 2006). Although the term 'level' is used ambiguously in science, the concept used here is that of 'grades of being ordered', which captures what biologists and social scientists refer to as 'levels of organisation' (Bunge, 1960). Three such grades or levels can be identified at which OH outcomes are usually measured: individual level of health, population level of health and ecosystem level of health (Lerner and Berg, 2015). Systems can be considered as a network of components, which can be tangible (e.g. humans, animals, forests, lakes) or intangible (e.g. cultural behaviours, values, norms, language expressions) and which are linked by interactions (Anderson and Johnson, 1997; WHO, 2009). The system's components depend on the perspective and determine its boundaries, which are important for evaluation (Garcia and Zazueta, 2015). While the perspectives of stakeholders (and thus system boundaries) may differ, the stakeholders may become agents of change or part of a pathway towards successful solutions (Ostrom, 2009; WHO, 2009; Williams, 2016). OH initiatives might create additional opportunities to produce relevant – expected as well as unexpected – outcomes by including stakeholders and system boundaries explicitly (Figure 3.2).

3.3.1 The general overview

For the general overview, the evaluator should put together a concise description of the background, objectives, key features and rationale of the OH initiative under evaluation so that the user is aware of the important characteristics that can affect the evaluation.

3.3.2 Visual representation and textual description of the context

Here the focus is specifically on the system targeted by the OH initiative; in other words the wider context within which the initiative operates. We will describe the initiative itself later. For the visual representation of the system (Figure 3.3), we propose a combination of the socio-ecological system framework by Ostrom and a causal loop diagram (Anderson and Johnson, 1997; Ostrom, 2009).

To capture the socio-ecological system, three core subsystems are plotted first (Figure 3.3): the resource systems (blue ovals), the resource units they provide (blue boxes), and the governing systems (grey boxes). In the next step, further tangible and intangible components relevant to the system (white ovals, e.g. use of antibiotics, effectiveness of antimicrobials) are added. For legibility of the graph it is recommended to use nouns that fit into phrases such as 'the level of…', to avoid verbs and to use neutral terms, e.g. 'use of antimicrobials' rather than 'increase of antimicrobial use'. Finally, relationships are added as arrows: governance relations (grey), membership relations (black) and causal relations (blue). For causal relations, it is useful to note the relation using S for same direction change and O for opposite direction change, in order to identify reinforcing and balancing loops at a later stage. Subscripts and explanatory text as well as annotations of time delays can be convenient for later reference.

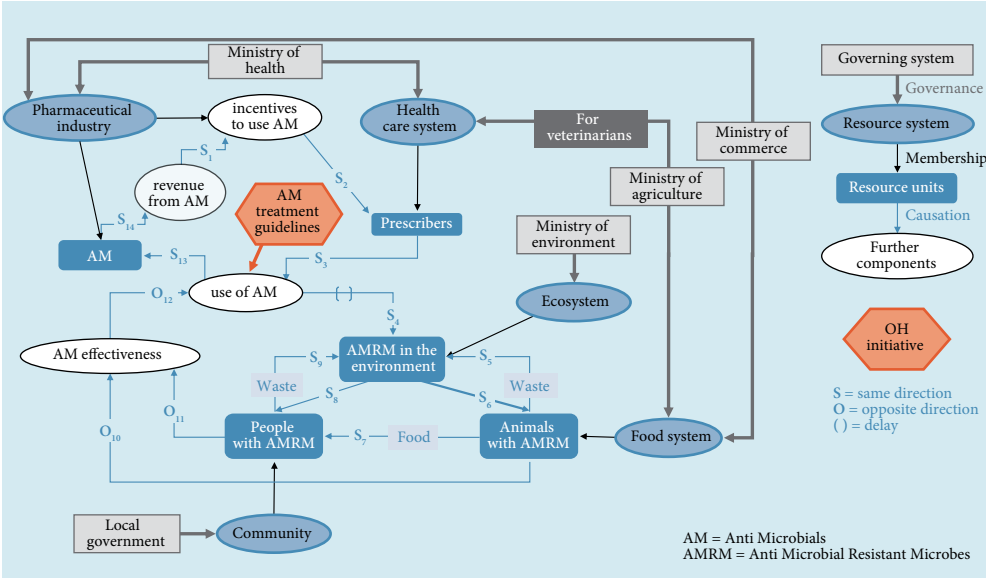

Figure 3.3. Example for visual representation of an initiative in its context exemplified by occurrence of antimicrobial resistance within a given system: resource systems (blue ovals), resource units (blue boxes), and governance systems (grey boxes) within which an initiative operates. Furthermore, tangible and intangible components (white ovals) are included. Relationships (arrows) are classified as governance (grey), membership (black) and causal interactions (blue) with explanatory text. Letters designate changes of two components in the same (S) or opposite (O) direction, respectively. The red hexagon represents the initiative with arrows where it impacts the system. Published in (Rüegg *et al.*, 2018).

Visual representation is powerful, but lacks any dimension beyond the plane and therefore hinders the depiction of overlapping sub-systems or nested hierarchies. Hence, to explore further the system in which the OH initiative operates, the textual description is guided by three questions formulated by Williams (2016): (1) to understand interrelationships: What is the reality we are dealing with?; (2) to engage with perspectives: How do we understand/how do we see that reality?; and (3) to reflect on boundaries: How do we decide to do what needs to be done? (Williams, 2016). In Table 3.1 we adapted the tabular system description by Boriani *et al.* (2017) for a broader application. It allows capturing aspects complementary to the graph and sometimes overlapping, namely the aim of the system, the stakeholders and actors and their interactions, the system dimensions with corresponding boundaries, and the system evolution.

The aim and/or indicators of the system are not to be confused with the aim of the initiative and should answer the question 'why does the system exist?' or 'what does it produce?', e.g. the result of a food chain may be to 'produce Salami'. A social-ecological system may not have an explicit aim, but it can be characterised by indicators that allow the description of selected attributes, such as resilience, productivity or health. In this evaluation framework, we differentiate between the declared aim by the system and the observed, enacted and the perceived aims. The declared aim of a veterinary practice may be to provide animal health services. However, this will be enacted within a socio-economic context, which may result in therapeutic choices that prioritize practice income over animal welfare. These actions may be observed by a subset of clients, while others do not notice them. Each stakeholder may have a different perception of the declared aim and again, each of them can have a different way of interpreting how the system is performing in relation to its aim (Anderson and Johnson, 1997). In socio-ecological systems the perceptions differ mainly in regard to the way one verifies if the system is intact/healthy. This is important as it explains the motivational background of the concerned stakeholders. If the system has an explicit aim, specific indicators should be identified and compared to indicators used by stakeholders to assess their perceived aim(s), thereby shedding light on discrepancies and identifying ways of resolving them.

Following the interactive terminology for Europe (Anonymous, 1999), we define stakeholders as 'any individual, group or organisation who may affect, be affected by, or perceive themselves to be affected by a decision or activity', while actors are a subgroup of stakeholders such as 'any individual, group or organisation who acts, or takes part' in system activities. To gain clarity about roles of stakeholders, we recommend referring to the visual representation of the system exemplified in Figure 3.3 and probe for 'who is involved in the system as an actor and who is merely affected?'. For example, the pharmaceutical industry produces a certain compound, people can decide whether to take that compound or not, while animals are affected by a certain preparation distributed to them by an actor in the system (e.g. veterinarian or owner). An overview of relevant actors and stakeholders allows further delimiting the system under evaluation. Stakeholders could be actors at the same time, and in these situations, the capacity that a group is stakeholder or actor, respectively, should be differentiated.

In order to understand the context of the OH initiative, it is important to understand how the components of the system are arranged or interact (Williams, 2016). There are four aspects of relationships that should be considered and described: (1) the structure or arrangement

Table 3.1. An overview of how to describe the system at which the One Health initiative is targeted, i.e. the context of the initiative (adapted from Boriani *et al.*, 2017).

Aspect	Description	Secondary questions	Evolution
Aims	What is the context of the OH initiative - why does this system exist? What does it produce? For social-ecological systems that have no explicit aim, what are indicators that the system is intact/ healthy?	Perspectives • What does the system aim to do? Are there different declarations? • What do the actors and stakeholders perceive the system does and how do those perceptions differ? (For social-ecological systems: how do the actors and stakeholders perceive/evaluate that the system is intact/operational?) • Are there measurable outcomes/ indicators of the system? • How do the declared, perceived and measured aims/outcomes relate?	Do the various aims/ indicators change as the system evolves with time?
Actors	Who are the actors? Who acts within the system?	Relationships • How do they affect the other actors/ stakeholders and the aim of the system? • How are they affected by the other actors/stakeholders and the aim/ indicators of the system? • How are the relationships distributed/ arranged? • Which are the most important links? • What are the processes between the related components? • How can the links be characterised (slow/fast, strong/weak)?	Do the actors change their activity and behaviours as the system evolves (new trade-offs)? Does the system have secondary effects on the actors?
Stakeholders	Who are the stakeholders? Who is affected by the system?	Relationships • How are they affected by the actors and the dynamics of the system? • How are the relationships distributed/ arranged? • Which are the most important links? • What is the nature of the processes between the related components? • How can the links be characterised (slow/fast, strong/weak)?	Does the system have secondary effects on the stakeholders?

Table 3.1. Continued.

Aspect	Description	Secondary questions	Evolution
Geographical dimension	Which geographical space does the system occupy and where is it situated (surface concerned, climate, location)?	Boundaries • How is the system delimited in geographical area? • How do these boundaries affect the system aims/indicators and dynamics?	Does the system have secondary effects in geographical space within the boundaries? Does the system produce 'externalities' in geographical space?
Temporal dimension	Which is the most important time scale in which events are happening in the system (e.g. minutes, months, years)? Are there other important time scales?	Boundaries • How is the system delimited in time? Is it infinite, terminated, transient? • How does this time limit affect the system aims/indicators?	Does the system affect the frequency of events or its own time limit? Does the system produce 'externalities' in time (accelerating or slowing down external systems)?
Governance/ institutional dimension	Which governance entities/levels are involved (shire, agglomeration, state, nation, or international space)? What institutional structures (companies, corporations, organisations) play a role?	Boundaries • How is the system delimited in the governance/institutional dimension? • How do these boundaries affect the system aims/indicators?	Does the system have secondary effects in the governance/ institutional dimension within the boundaries? Does the system produce 'externalities' in the governance/ institutional dimension?
Further dimensions	How does the system extend within this dimension and how many levels of this dimension are part of the system?	Boundaries • How are these dimensions delimited? • How do these boundaries affect the system aims/indicators?	Does the system have secondary effects in these dimensions within the boundaries? Does the system produce 'externalities' in these dimensions?

of the links between the components (topology); (2) the nature of the processes between the components (e.g. information flow, transfer of goods, etc.); (3) the characteristics of the links (slow/fast, strong/weak, antagonistic/synergistic, etc.); and (4) identifying the links that are most important in the system.

Dimensions are defined as spaces in which levels of organisation according to Bunge occur (Bunge, 1960). In other words, entities within a dimension feature the same quality (e.g. metric) but to a different degree. Examples include geographical space, time, governance/institutional, economic, linguistic, faith and value dimensions. Within these dimensions we consider scales or levels of analysis, e.g. cell – organism – population in the dimension of life (Pumain *et al.*, 2006, pp. 39-70). These levels are important, because they will determine the relationship between the resolution of the analysis and the resolution of observations and what can be measured or evaluated in the system in a particular dimension. Due to their importance, geographical, temporal and governance/institutional dimensions are included.

Time, in particular, is related to the scale in other dimensions, i.e. the larger the system the larger its characteristic time, which is the time at which average change occurs (e.g. cells react within milliseconds, individuals between minutes and hours, ecosystems between years and decades; the same applies to the adaptability of laws at different scales or the frequency that vocabulary is used in a language) (Pumain *et al.*, 2006). Together with geographical space, time is a particularly important dimension, because it will characterize if the system is evolving over seconds, hours, days, years, decades or even longer. It can be considered in the past, present or future, and opportunities to affect the system are highly dependent on time due to the system disposition (the same intervention may have different effects when applied at different times). Furthermore, causes and effects may occur in different time scales, where short actions may result in effects with a time lag of years. The governance/institutional dimension will determine which organisational levels (ranging from international governance mechanisms to household structures) are represented and addressed in an initiative. Considering scales is important, because initiatives may aim to change systems at several different levels according to the most promising leverage points. Consequently, well intended initiatives may remain ineffective if they do not address all appropriate levels.

Further dimensions are the 'dimension of life' (or 'biology') comprising nested living entities from cells to biosphere with levels such as 'cell', 'organ' and 'individual', the 'economic dimension' defined by rules and institutions involved in production, trade and exchange of goods and services, the 'linguistic dimension' delimited by languages and dialects used, and the 'faith/value dimension', which represents the values and beliefs underlying the system. Other dimensions may also be relevant to the system, such as communication, transportation, legal frame, socio-cultural dimensions and many others.

The primary importance of a systems approach to evaluation implies less the idea of being comprehensive, but rather being 'thoughtful, smart and aware about what you are leaving out' (Williams, 2016). The evaluator(s) will need to be transparent about the consequences of choices and declare their relation to the initiative, the system and the evaluation per se. Although the dynamics, boundaries and stakeholders of a system are clear, they will be constrained by physical limits (e.g. a mountain range, river), social limits (e.g. country, community), regulations (e.g. quotas, prohibitions) and/or other norms (e.g. social norms, religious norms) that are either imposed by the systems' nature or selected by the evaluators (Garcia and Zazueta, 2015). Many restricting factors will be found in the system dimensions identified earlier. For example, a food system can be limited due to production regulations (e.g. the previous milk quotas system in Europe), food hygiene standards (e.g. restrictions

on raw milk consumption), or cultural practices (e.g. no pork consumption in certain faith groups). The system boundaries characterise the interaction between the context of the initiative with the broader world in which it is imbedded, and determine how this affects the aim of the system (Garcia and Zazueta, 2015). Finally, dimensions can also interact and may even be closely correlated, to the extent that it may not be useful to differentiate them (e.g. when religious beliefs are prescribed by the law).

The evolution of a system can be regarded as interaction of time with other dimensions in terms of iterations and pathways along those dimensions and time. Apart from the aim of the system, the interactions in the system may produce secondary effects within the system and 'externalities' beyond the boundaries as it evolves. Highly self-organising systems may even change their (aim) dynamics and boundaries as time goes by.

3.3.3 Illustration and description of the OH initiative within the context

In a next step, the OH initiative can be added to the visual representation of the context to illustrate its effects on various components and their interactions (Figure 3.3). If an affected component is missing, it is added and the system graph is corrected accordingly. In the example in Figure 3.3, we have included a hypothetical OH initiative that involves new antimicrobial treatment guidelines for veterinarians and general practitioners (prescribers) that are assumed to impact directly on the amount and distributions of types of antimicrobials used in the system.

The user should now have a clear understanding of the system in which the OH initiative is situated. Next, the initiative itself is described using the template in Table 3.1 in analogy, namely as a nested subsystem of the context which it aims to change. Many elements may be congruent, but the boundaries of the initiative will inevitably be smaller and there will be fewer actors, stakeholders and more limitations than in the description of the system. Care should be taken, as actors and stakeholders and their particular roles may not be identical in the initiative and in the wider system. The initiative may be likely to consider fewer dimensions compared to the system, but it is important to identify how it will influence the context and what the limitation of the actions are. A key question in this description is: How is OH conceptualised by the various participants and is there a common understanding?

3.4 Element 2: the theory of change, outcomes, evaluation design and implementation

Element 2 involves an elaboration of the TOC, which helps to explain how an initiative is intended to produce the desired (or expected) outcomes. This is an important step to define the evaluation question and to choose the evaluation methods and metrics. It entails generating hypotheses about the causal mechanisms by which the components and activities of the initiative produce outcomes by asking pertinent questions about: (1) why people expect the initiative to bring about the change(s) and the outcome(s) they seek, (2) to question their assumptions about how the change process will unfold, and (3) to be clear about how they are selecting outcomes to focus on, in the evaluation. Identifying and developing a theoretical understanding of the likely process of change is a key task to evaluate successfully complex

initiatives (Craig *et al.*, 2013). It also provides an opportunity for stakeholders to assess what they can influence, what impact they can have, and whether it is realistic to expect their goals to be reached with the time and resources they have available.

Measuring (or assessing) change in multiple outcomes, facilitates the evaluation of whether the OH initiative works as intended and whether it is cost-effective. In addition, unexpected outcomes may arise from an OH initiative. A good description and understanding of the system and OH initiative in Element 1 facilitates the identification of interactions and dynamics that may lead to unexpected and indirect outcomes not specified by the TOC. This framework standardises the evaluation through a systematic approach based on the TOC, while explicitly remaining open for potentially emerging systemic effects through non-linear impact evaluation (Figure 3.2). During the implementation of an initiative, the TOC can be reviewed based on progress. Retrospectively, it helps to inform a reflective process of learning about what has worked and why, as part of an evaluation process (Taplin *et al.*, 2013).

3.4.1 Description of the theory of change

Essentially, the TOC presents a roadmap with all the building blocks required to bring about a desired (long-term) goal; it hence, spells out the logic behind the initiative. The presentation of the TOC can be assisted by a graphical presentation (e.g. Figure 3.4), or the TOC description can refer back to the illustration of the system used in Element 1.

The impact is defined as the long-term effects (or goals) to be induced by an OH initiative. It is a change that continues to exist after the end of the initiative, and can be a direct (first order) or indirect (second order) impact. Outcomes are changes (e.g. improvement, learning) resulting from the initiative that can be considered to be stepping stones for progress towards the longer-term goals. In a transdisciplinary process, the outcomes are situated in societal and scientific practice and can be of multiple natures (e.g. technical, economic, social, sanitary, political) (Lang *et al.*, 2012). Outputs are products, goods and services, which result from the transdisciplinary process of an OH initiative and are necessary for the achievement of outcomes. For illustration, we use an example from a fictive research project aiming to produce new knowledge and methods to combat the development of antimicrobial resistance (Figure 3.4): OH research outputs (new data and knowledge) result in new treatment guidelines (outcome) leading to new regulations restricting (and hence lowering) the use of specific antimicrobials in farmed animals (first order impact of political nature), which then may reduce the development of antimicrobial resistance in farmed animals and the associated transmission to people (second order societal impact). The impacts can be realised at different political levels (e.g. individual, institutional, regional, national, international) and can consist of different types of effects (positive or negative; direct or indirect). Outcomes for societal and scientific practice (e.g. an improved integrated surveillance programme for antimicrobial resistance or a new simulation model, respectively) are disseminated, adapted and applied by other actors, resulting in societal impact or scientific progress. Between the initial problem formulation and the expected impact(s), new inputs might be required as a result of intermediary outcomes and will feed a further iteration of knowledge co-production. An example could be new research collaborations such as the outcome of an OH initiative, which may lead to new knowledge or tools for improved control of infectious diseases in

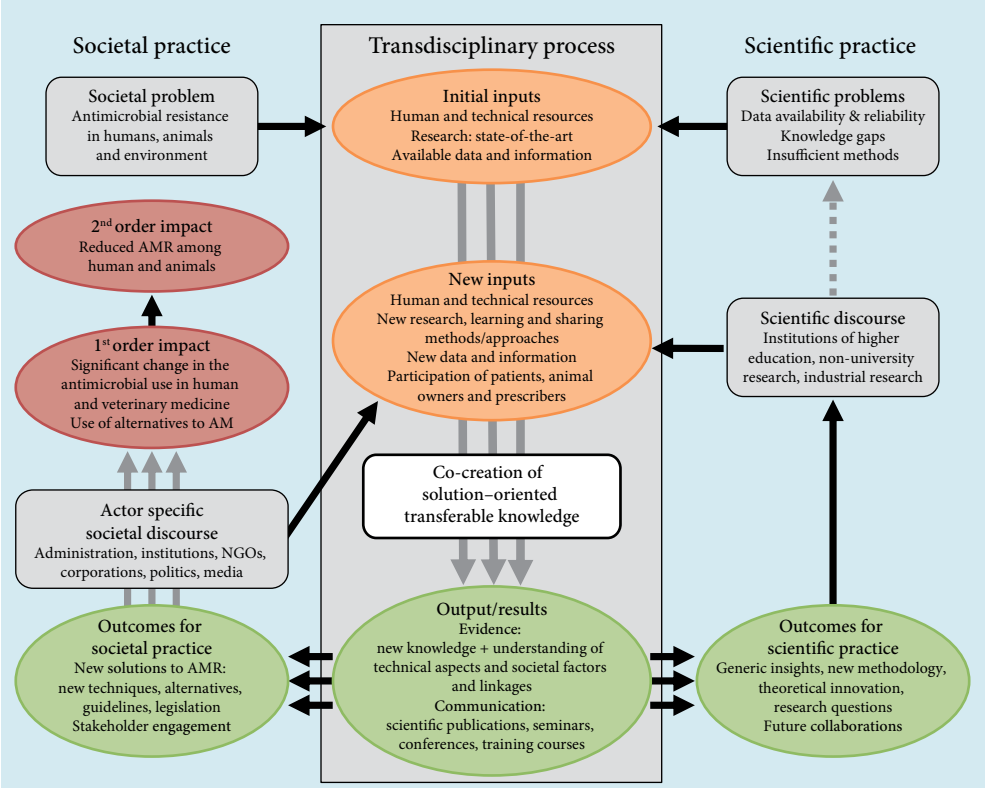

Figure 3.4. The change pathway for a fictive One Health research initiative aiming to mitigate the development of antimicrobial resistance in a transdisciplinary process. It illustrates the inputs from science and society to co-produce outputs that are taken up by society and the scientific community and disseminated through a specific discourse before resulting in first and second order impacts and scientific progress. On the way to impact(s), several iterations with new inputs and outputs of the transdisciplinary process may be needed. Published in (Rüegg *et al*., 2018).

a second initiative. The sequence of inputs (i.e. resources needed to perform the actions), outputs, outcomes and impact can be graphically represented by a change pathway also known as an impact pathway (Taplin *et al*., 2013) or a logical framework or logic model, which presents the flows in a 'logical', sequential way (Brown, 2016). Importantly, the classification into outputs, outcomes and impacts depend on the perspective that is taken for the evaluation and may differ among stakeholders (INTRAC, 2015). It is therefore important to elaborate the TOC in collaboration with the entity contracting the evaluation.

To generate a TOC, stakeholders must be clear about what they want to achieve with their initiative. In a OH team it is likely that the group members often have very different ideas about what they are working towards and are lacking a joint understanding. Therefore, everybody involved should agree on the preconditions – the building blocks – that must exist

in order to reach their long-term goal. They then need to consider, in light of this big picture perspective, which of these preconditions they will take responsibility for producing – both individually and as a team.

Six main steps are recommended in the evaluation to build up this change pathway:

1. Writing a narrative to explain the logic of the initiative.
2. Identifying basic assumptions about the context.
3. Identifying long-term goals.
4. Backwards mapping and connecting the preconditions or requirements necessary to achieve that goal and explaining why these preconditions are necessary and sufficient.
5. Identifying the activities that the initiative will perform to create the desired change.
6. Identifying and/or developing indicators to measure outcomes to assess the performance of the initiative.

This mapping exercise could be done using participatory approaches and tools such as actor consultation workshops; expert opinion elicitation process; outcome mapping; individual or focus group; convergent interviews (e.g. key informant), questionnaires (e.g. internet), expert reviews, Delphi studies, Dotmocracy, ORID, or Q methodology, among others. Particularly outcome mapping can be a useful tool to use for OH initiatives, either in combination with TOC or on its own if it fulfils key assumptions of dependence on human behaviour, limits to the influence of interventions, active contribution of people to their well-being, co-existence of differing yet valid perspectives, and resilience dependent on interrelationships (Deprez, 2014).

Usually there is just a subset of outcomes that OH collaborators can influence. Some preconditions are beyond the sphere of influence of any single initiative, such as needing a stable economy to produce enough jobs to reach an employment goal. Others may be beyond a programme's influence, but stakeholders could suggest ways that a particular programme may be able to influence other programmes, or they could identify areas for strategic collaboration or partnerships. Combining different options during the process can provide more insightful understandings by: (1) identifying issues or obtaining information on variables not obtained by quantitative surveys; (2) generating hypotheses to be tested through the quantitative approach; (3) understanding unanticipated results from quantitative data; or (4) verifying or rejecting results (triangulation).

3.4.2 Expected outcomes and impacts

The description and definition of outcomes and impacts are dependent on the problem the OH initiative is addressing and the associated boundaries of the system, objective, rationale and consequently the resulting TOC. Given the diversity of OH initiatives, there is no single outcome that summarises OH endeavours, but rather a wide range of different outcomes (Baum *et al.*, 2016; Falzon *et al.*, in press; Häsler *et al.*, 2014a). However, at the longer-term impact level, there are commonalities that OH endeavours to strive for (Rüegg *et al.*, 2017). The outcomes and impacts to be measured need to be selected as a best fit for the specific OH

initiative and its TOC. Because of their nature, OH initiatives will commonly span different sectors and disciplines and therefore are likely to produce disciplinary, interdisciplinary and OH outcomes and impacts. Evaluators consequently need to be aware of disciplinary paradigms, data and approaches as well as methods of combining outcomes from different disciplines. A range of outcomes used in the fields of social, ecological and economic assessments are presented in the following chapters. Here we limit ourselves to the distinction between disciplinary, interdisciplinary and systemic OH outcomes.

Disciplinary outcomes relate to outcomes that are measurable within a distinct discipline or sub-speciality within the natural or social sciences. Examples of disciplinary outcomes include health outcomes such as decreased levels of non-communicable or infectious diseases; nutrition outcomes such as reduced levels of undernutrition or obesity; economic outcomes such as increased productivity or savings in the health care system; social outcomes such as improved societal stability; and ecological outcomes such as slower rates of biodiversity reduction or improved water or air quality. Importantly, these outcomes can be achieved in disciplinary or sectoral approaches (e.g. promotion of a new anti-diabetes treatment or childhood vaccination in a national health service), but more often, they are the results of collaborations across disciplines and sectors. Interdisciplinary activities, by definition, have an impact on multiple fields or disciplines and produce results that feed back into and enhance disciplinary or sectoral work. In these instances, the pathway to the outcome may be characterised by collaboration and contributions from different disciplines and sectors, but the outcomes may still be conceptualised (and consequently measured) at the level of a field or discipline. Combining these disciplinary outcomes in methods such as multi-criteria decision analysis gives a solid basis for an assessment of the achievements of the OH initiative. In interdisciplinary outcomes, the efforts realised by individuals from different disciplines getting together to create new knowledge and understanding through sharing of ideas and bringing together different perspectives result in a product or measure, which explicitly reflects the shared responsibility among disciplines for outcomes (Strang and McLeish, 2015; Trochim *et al.*, 2006; WHO, 2009). Consequently, interdisciplinary outcomes occur in the realm of at least two disciplines simultaneously, e.g. food security as an interdisciplinary outcome of successful alignment of multiple sectors (i.e. food availability, food access and food utilisation), which contribute different skills and expertise (Ingram and White, 2015). Other examples are the Human Development Index, the Environmental Performance Index, and the Planetary Boundaries, which combine a diversity of indicators into a single or a few measure(s). An improvement in the index cannot be achieved with a disciplinary approach, but needs activities in health (e.g. investment in health service capacity, public awareness campaigns), education (e.g. build infrastructure, attract talented teachers, provide incentives for school attendance), social protection (e.g. policies to reduce poverty and vulnerability of disadvantaged population groups), and economics (e.g. promotion of efficient labour markets, robust governance). Interdisciplinary outcomes are ideally measured in a common metric, i.e. they should rely on a consensus on how to assess and weigh the particular outcomes. Such metrics are even more policy relevant and effective if they are produced and measured in a transdisciplinary process, which transcends both horizontal boundaries between scientific disciplines, and vertical boundaries between science and other societal fields (private sector, public agencies and civil society) (Lélé and Norgaard, 2005). Through the process stakeholders

share different perspectives and can therefore improve the contextualization of the problem and its potential solutions and targets (Hirsch Hadorn *et al.*, 2008).

OH outcomes or impacts occur as result from a broader integration of activities in the system at stake. The main domains of OH outcomes are the three pillars of sustainability, i.e. society, environment and economy. Typical examples are interspecies equity, health stewardship, human and animal welfare, efficiency and effectiveness (Rüegg *et al.*, 2017). Clear causal attribution to the OH initiative may be difficult, but a contribution of the OH initiative can be assessed. An overview of the links between the OH characteristics (Figure 3.1) and some OH outcomes is available as supplementary online material (ESM-1).

Given the perspective chosen and the resource availability for the evaluation, the description of the TOC and the selection of associated outcomes may be more or less comprehensive and complex. However, the evaluator should make sure to pay careful attention to the contributions from different disciplines and sectors, their integration and the resulting positive and negative effects.

While One Health appears to be an endeavour towards sustainability and resilience relying on the three pillars of society, economy and the environment (http://www.un.org/sustainabledevelopment/), deficiencies in any of these aspects is obviously a reason to engage in OH (Rüegg *et al.*, 2017). Similarly, any driver for OH can be understood as the negative expression of the desired outcome, e.g. disparity versus equity, illness versus health, etc. Consequently, any driver identified earlier can be measured as an outcome of the OH initiative, and progress over time may convert what was considered to be a driver (a problem) into some form of improvement (a positive outcome).

3.4.3 Unexpected outcomes and impacts

By definition unexpected outcomes and impacts cannot be planned or covered by a TOC, even though attempts are sometimes made to capture a wide range of eventualities. Throughout a OH initiative within its system, interactions among components and feedback loops frequently produce rapid, non-linear and unanticipated changes (Fath *et al.*, 2015; Garcia and Zazueta, 2015; Reynolds, 2015). Typically, integrated approaches in complex systems generate unexpected added value, e.g. a new stakeholder organisation, but may also result in unexpected negative impacts, e.g. discrimination among stakeholders (Garcia and Zazueta, 2015), which is why capturing unexpected outcomes constitutes an essential process of OH evaluation. Other examples would be emerging diseases due to new contact rates or closer contact between previously isolated populations, or due to new social behaviours in urbanised environments (Wallace and Wallace, 2016). If unexpected outcomes are not captured, evaluation fails in informing adaptive management that seeks to improve outcomes in complex dynamic environments (Mowles, 2014). Some exemplary methods to capture unexpected outcomes and impacts are presented in the section on non-linear impact assessment (Section 3.4.4.2).

3.4.4 Evaluation design and selection of outcomes

3.4.4.1 Consider/select evaluation question(s)

It is important to select the appropriate evaluation questions before conducting the evaluation to avoid wasting scarce resources by evaluating aspects that are not of interest to end-users. During the planning it is therefore recommended to look at the TOC and to reflect on what exactly stakeholders want to know about the initiative. This should clarify why the evaluation is conducted and why the community of interest, the team, the funding bodies or other stakeholders may be interested in the evaluation. Different types of evaluation questions may be important, which will also influence the selection of the evaluation type. Adding questions during the evaluation may be possible (e.g. non-linear impact assessment), but may be difficult for others with more rigid evaluation designs (e.g. impact evaluation). It may be useful to include a brainstorming sessions with all stakeholders to come up with a full list of questions and then refine it based on priorities and resources available.

If the purpose of the evaluation is about learning and finding out how to improve the programme, the following questions may be important:

- Are the activities being implemented as planned?
- What works and what does not work?
- What are the strengths and weaknesses?
- What are participants' reactions?
- What works for whom in what ways and under what conditions?
- How can outcomes and impacts be increased?

If the purpose is about the performance, the following questions may apply:

- Does the programme meet participants' needs?
- Is there a gap between the intended and actual population served?
- How can quality be enhanced?
- Does the programme work as intended?
- To what extent can outcomes be attributed to the intervention?
- Is the programme theory clear and supported by findings?

If the purpose of the evaluation is about economic efficiency, the following may be relevant:

- How can costs be reduced?
- Does the programme deliver value for money?
- Could a higher outcome be achieved at the same cost?
- Is one strategy more beneficial than the other one?
- How do outcomes and costs compare with other options?

3.4.4.2 Select evaluation type

Taking into account the information gathered so far, the user needs to make a decision on the evaluation type to be used taking into account the complexity of the OH initiative, its rationale, and the scope and purpose of the evaluation. There are three main evaluation types

that need to be considered in this process, namely impact evaluation, non-linear impact assessment and economic evaluation, which are briefly explained in the following sections.

Impact evaluation

Impact evaluation (IE) seeks to show that intended results are achieved as a result of a programme's activities, directly or indirectly. In other words, IE tries to identify whether a programme or policy as a cause can be linked to identifiable and intended results. This is often described as making a 'causal claim'.

Impact evaluation belongs to the broader agenda of evidence-based policy making. By making programme processes and resulting effects more transparent, IE proves or disproves accountability to funders and policy makers. It is concerned with both demonstrating and measuring effects as well as explaining these effects, to be able to answer 'how' and 'why' questions. It can also help us understand how to do things better and more accurately in the future. The need to explain the effects highlights the importance of theory and of context, in order to address questions of generalisability beyond a particular programme evaluation.

To decide whether to perform an impact evaluation, it is generally worth performing first a preliminary assessment to collect information on the topic of interest, the relevance of the intervention programme (e.g. what is the innovative and influential potential; what is the number of people who are or will be affected by it) and the feasibility of the impact evaluation (e.g. financial resources and logistics; ethical, political or other constraints prohibiting randomisation in a controlled trial; incomplete baseline data to allow for comparison with and without the intervention). Based on this information, a decision can be made on whether a full-scale impact evaluation needs to or can be conducted.

Once it is decided to conduct an impact evaluation, the further design implies important decisions which are determined by the hallmark of IE, i.e. the focus on causality and attribution. Three basic factors need to be taken into account when deciding on a suitable IE design: (1) the evaluation questions to be answered; (2) the 'attributes' of the programmes to be evaluated; and (3) the realistic capabilities of available designs. Many decisions related to those factors are interconnected.

Evaluation questions

The selected evaluation question may need to be refined further to capture the essence of an impact evaluation. Four typical questions in impact evaluation are the following:

- To what extent can a specific impact be attributed to the intervention?
- Did the intervention make a difference?
- How has the intervention made a difference?
- Will the intervention work elsewhere?

Because pre-existing theory rarely exists for OH initiatives, it is important to take into account the elaborated TOC (Section 3.4.1) to capture the expected dynamics. Additional questions that are likely relevant for the impact evaluation of OH initiatives include the following:

- Is the work consonant with/grounded in its source disciplines/methodologies or is it likely to develop novel methodological approaches?
- Has the work added or will it add to knowledge, even in a non-conventional way?

Programme attributes

The attributes of programmes, including their purpose, form, location, inter-relationship results and duration, can highly vary. These attributes affect the impact evaluation design and the questions. Many OH initiatives are likely to be in areas of limited understanding or they overlap with other interventions with similar aims and their results are difficult to measure. Consequently, precise attribution questions will increase the complexity of the evaluation design required and resources needed (including capacity).

Impact evaluation designs

In IE, a link between cause and effect needs to be established. This link can be established through comparison of: either two populations at the same time, with and without intervention, ensuring there is no mixing; or of the same population in time, before and after the intervention. The basic questions concerning an evaluator regarding the choice of the design are:

- What do we want to measure (e.g. a disease incidence rate)?
- How could we measure it (e.g. is an experimental approach feasible?)?
- What are assumptions on the measurement (e.g. is the way we detect cases stable over time)?

The key to useful IE is a sound methodological approach including high quality data, addressing issues of most interest for policy and programme makers (it may be advisable to focus on fewer or one particular question to be addressed) and to acknowledge the limitations of the factual analysis of the causal chain and its assumptions. For many OH initiatives, it may be more appropriate to combine the effort with a robust non-linear impact assessment (see next section). Given that no single approach seems to provide a complete picture, mixed designs (i.e. using a variety of methods, quantitative and qualitative) are most useful in strengthening confidence in conclusions. For instance, an IE could combine an experiment to assess the impacts of a programme, with a participatory design to ensure validity and relevance, and case-based, comparative studies to identify the implications of different contexts. In principle, IE for OH follow the generic guidelines, for instance explained in detail by Gertler *et al.* (2011) and Stern (2015). The main designs useful for IE, their variants and causal inference (i.e. way to show the link between cause and effect) are given in Table 3.2.

There is not always a need for a full-scale extensive impact evaluation. If a full impact evaluation is not deemed feasible, encouragement designs (e.g. a real-time, formative evaluation) can be used to test different approaches and to extract estimates of the programme's impact. Having to refer to approximations is quite likely, because OH outcomes and impacts are expected in society, ecosystems and economy, and hence the IE must be informed by the vast field of methods from social assessment, environmental and/or economic evaluation outlined in Chapters 4-6. The main issue here is that most of these investigations do not provide causal

Table 3.2. Main designs used in impact evaluation, their variants and causal inference (Stern, 2015).[1]

Design approaches	**Variants/methods**	**Basis for causal inference**
Experimental	Randomised controlled trials Quasi experiments Natural experiments	Counterfactuals: the difference between two otherwise identical cases – the manipulated and the controlled; the co-presence of cause and effects.
Statistical	Statistical modelling Longitudinal studies Econometrics	Regularity: Correlation between cause and effect or between variables, influence of (usually) isolatable multiple causes on a single effect. Control for 'confounders'.
Theory-based	Causal process designs: Theory of change, process tracing, contribution analysis, impact pathways. Causal mechanism designs: Realist evaluation, congruence analysis.	Generative causation: Identification and confirmation of causal processes or 'chains'. Supporting factors and mechanisms at work in context.
Case-based	Interpretative: Naturalistic, grounded theory, ethnography. Structured: Configurations, QCA, within-case-analysis, simulations and network analysis.	Multiple causation: Comparison across and within cases of combinations of causal factors. Analytic generalisation based on theory.
Participatory	Normative designs: Participatory or democratic evaluation, empowerment evaluation. Agency designs: Learning by doing, policy dialogue, collaborative action research.	Actor agency: Validation by participants that their actions and experienced effects are 'caused' by the programme. Adoption, customisation and commitment to a goal.
Synthesis studies	Meta-analysis, narrative synthesis, realist-based synthesis.	Accumulation and aggregation within a number of perspectives (statistical, theory based, ethnographic).

[1]Contains public sector information licensed under the Open Government Licence v3.0.

relationships, but they can be more informative when exposed to counterfactual thinking and quasi-experimental designs that collect data as to reveal hidden biases.

A list with references to detailed guidelines on impact evaluation for evaluators and risk managers, and databases with past and current development programmes, including health, is available as supplementary online material (ESM-2).

Non-linear impact assessment

An expanding array of methods for complexity-enabled monitoring, evaluation and learning (CeMEL) is available for use in the fields of development and peacebuilding (Befani *et al.*, 2015; Britt, 2016; Chigas *et al.*, 2014), many of which can be contextually adapted for One Health projects and programmes. A recent edition of the IDS Bulletin (Befani *et al.*, 2015) is entirely dedicated to methods, questions and approaches necessary to embrace complex systems. In the following sections, we will briefly describe some qualitative and quantitative methods and refer to more detailed sources.

Due to the complexity of OH initiatives, their diversity of stakeholders, actors and objectives in human, animal and ecosystem health, the use of CeMEL is almost imperative. We therefore recommend to implement at least one of the mentioned methods to remain aware and attentive to possible emerging features that result from such a holistic approach. This not only helps avoiding unintended negative consequences, but also contributes to demonstrating the added value of a holistic approach in contrast to a focussed initiative.

Qualitative methods embracing complexity

The advantage of using qualitative methods in CeMEL is that they are less constrained in measuring progress towards a predefined goal and can be used to engage stakeholders in participatory processes. A discussion note produced for the US Agency for International Development recommends five approaches for complexity-aware monitoring without claim for completeness (Britt, 2016):

1. Sentinel indicators are the most basic way to complement a TOC-based evaluation system with a complexity-aware approach (Britt, 2016). The concept is borrowed from ecology where it refers to an indicator which captures the essence of the process of change affecting a broad area of interest and which is also easily communicated. As such, a sentinel indicator facilitates monitoring and communicating about complex processes that are difficult to study within a OH initiative. As a proxy, however, this type of indicator provides incomplete information, and judgments about complex processes or entire social systems based on a single indicator can be dangerous. Therefore, a sentinel indicator should be used to trigger further observation or probes.
   The identification of sentinel indicators begins with a description of the system at stake or a system map. Sentinel indicators are critical points in the map to help monitor and inform the mutually influencing relationship between the initiative and its context. These critical points are similar to leverage points mentioned in Table 3.3. Effective sentinel indicators signal changes in the relationships among actors, represent key perspectives separate from those of the initiative, or are placed outside the boundaries of an initiative.
2. The most significant change (MSC) technique focuses first on collecting and selecting stakeholder accounts of significant changes that have occurred during a specified time period, then following a structured process in discerning which changes are the most significant and why (Davies and Dart, 2005). The MSC approach validates the stories provided by stakeholder process of cross-validation with other sources. But in its essence, it is an inductive, goal-free method

with no pre-determined notion of what impacts ought to have been achieved – both positive and negative. The foundation of the approach is the systematic collection and selection of a sample of significant change stories from people most directly involved with an intervention (such as participants, field staff, affected community members). They are asked a simple, open-ended question: 'what was the most significant change that took place for your community' (in a particular domain, such as relationships among people, over a particular period of time)? The most significant of the stories are selected through a multi-layered group process of review, selection – often (although not always) involving participants and community stakeholders. The deliberative engagement helps programme implementers learn how local stakeholders view their environment and the various aspects of change that occur over time and space. MSC is not intended as a stand-alone methodology for evaluating impact. It is an inductive method that is best utilized as an exploratory tool that can be combined with other methods to further evaluate reported changes.

3. Also 'outcome harvesting' uses a participatory process to identify, formulate, verify, and make sense of outcomes, relationships and causal pathways (Wilson-Grau and Britt, 2012). It is focused on establishing the story of how an intervention has contributed to changes in behaviour of and relationships among actors intended to be engaged and influenced by the project. The method is particularly useful when there is difficulty in attributing impact to a particular programme because of diverse interacting actors and factors. Outcome harvesting looks for results that occur 'upstream' from an anticipated impact by focusing on the changes that occur within a programme's sphere of influence. It draws attention to incremental, often subtle changes that are necessary to support the large-scale, more prominent impacts in the system. In short, rather than looking for measureable 'quick wins', this method looks for the smaller sustained systemic changes in key actors and system factors that are necessary to sustain longer term system improvement. Outcome harvesting works in reverse from most standard evaluation methods by collecting evidence of what has been achieved, and working backward to determine whether and how the project or intervention contributed to the change. It relies on six iterative steps, which are outlined in detail by Wilson-Grau and Britt (2012): Design the harvest, Review documentation and draft outcomes, Engage with informants, Substantiate, Analyse and interpret the findings, Support use of findings. The World Bank (Gold *et al.*, 2014) has recently published the results of a pilot project examining 10 cases that explore outcome harvesting in development processes.
4. Monitoring approaches that privilege feedback from stakeholders or make use of participatory methods are particularly valuable in complexity (Britt, 2016). Diverse perspectives are important for at least two reasons. First, in complexity, knowledge of the system is partial and predictability is low. Second, how actors perceive a situation motivates their behaviour. Understanding the system from different perspectives will help any single actor create a more holistic and useful picture.

   Examples of stakeholder feedback include citizen report cards, community scorecards, client surveys or other forms of collecting opinions. Alternatively,

feedback may target those excluded from or marginalized by the initiative as a means of questioning whether the boundaries have been drawn in the most useful way. Sampling errors may include failure to properly identify the relationship between a respondent and an intervention, or capturing the responses of dominant individuals or groups only. Obtaining feedback may be costly and logistically or technically difficult to achieve. Measurements can be misunderstood and misreported.

5. Process monitoring of impacts (PMI) focuses on monitoring impact-producing processes (Britt, 2016). These describe how a result at one level is used by specific individuals or organizations to achieve results at the next level. In a sense, impact-producing processes take place between results. Like sentinel indicators and stakeholder feedback, PMI may be used to complement, rather than replace, performance monitoring systems.

Further approaches are described by the BetterEvaluation network (http://betterevaluation.org/en/approaches/), and organisations such as Cognitive Edge (www.cognitive-edge.com) provide tailor-made software and decision making tools based on micro-narratives in complex socio-ecological systems.

Quantitative methods embracing complexity

In circumstances where sufficient data exist, advances in computational analytics using non-linear modelling procedures and artificial neural networks have made it much easier to explore multivariate associations among indicators in complex systems. A straight forward alternative to linear models are Acyclic Bayesian Networks used to assess nested causality chains (Ward and Lewis, 2013). The method matches network models of causal factors to observational data in order to identify the most likely network which could have produced the observations. Although, allowing for much richer relationships among causal factors, the method does not consider feedback loops. An alternative approach is the risk propagation assessment as presented by Dellinger and Ehlinger, for example (Dellinger *et al.*, 2012). They used a 2-step methodology first employing self-organising feature maps (SOM, (Manolakos *et al.*, 2007; Novotny *et al.*, 2005)) to generate multidimensional clusters that visualize various outcome syndromes (e.g. ecological health, causes-of-death, and birth outcome metrics) and then applying supervised learning to identify key factors influencing dynamics of the system. The underlying propagation models typically consist of 4 layers (e.g. Figure 3.5) comprised of: (1) root stressors that act on a global, regional or local scale; (2) drivers of change that create exposure to risk factors; and (3) risk probabilities associated with exposures. These are typically expressed by numerical probabilities of undesirable hazards; and (4) impact endpoints reflect measures of system-related goods and services of value to the public.

Such risk profiles do not unequivocally demonstrate linear cause-effect relationships, but rather provide tools for identifying leverage points for targeted investigations and for risk-management prioritization. The profiles can be manipulated to simulate how the system changes in response to changing individual stressors alone or in combination. This process not only assists in producing a more robust understanding of the feedbacks, but also is an effective learning-enabling tool that helps facilitate situational-dependence, indirect effects and unanticipated consequences that single-issue interventions can have on the system. When

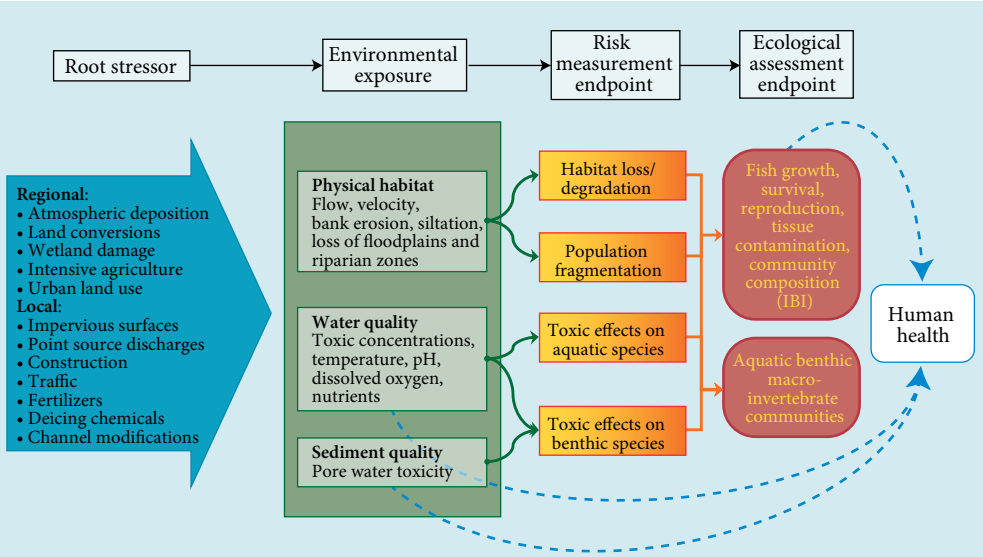

Figure 3.5. Example of a risk propagation model for an aquatic ecological risk assessment: Root Stressors act on a global, regional or local scale; Drivers of change create exposure to risk factors; Risk Probabilities are associated with exposures (typically expressed by numerical probabilities of undesirable hazards); and Impact Endpoints reflect measures of system-related goods and services of value to the public (courtesy of Timothy Ehlinger).

combined with systems mapping and critical examination of TOC process, risk profiling has the strong potential to identify key sentinel indicators (Britt, 2016).

Economic evaluation

An important claim of OH is that it generates an 'added value' through closer cooperation among professionals health, animal and environment sectors at all levels of organisation compared to uni-disciplinary or uni-sectoral approaches (Zinsstag *et al.*, 2012). Generally, there is an expectation that an integrated approach to the prevention and management of zoonotic disease risk leads to better disease control, prevention, and more efficient use of the scarce resources available (Rushton *et al.*, 2012). However, there is little evidence on the measured added value of OH in comparison to traditional approaches (Häsler *et al.*, 2014a), partly due to the complexity arising when value needs to be captured in humans, animals, society, and ecosystems. Expected benefits in OH include improved disease surveillance and control; better livelihood; more efficient production; greater health for humans, animals and ecosystems; food safety and food security; and avoidance of food scares (Häsler *et al.*, 2014a). However, greater integration, cooperation and collaboration in OH can also increase the resources needed for materials, operations, and labour. Time will be required to develop human, institutional and infrastructure capacities. These investments can be substantial, which brings up questions about who (private sector, public sector, NGOs), will be able to afford such an initial fixed capital investment (Häsler *et al.*, 2012). Consequently, the extra

cost needs to be valued and compared to resulting benefits to determine whether an effective action is also economically viable and justifiable.

Economic evaluations assign a value to the resources used in a specific action, and the consequences of such action expressed in monetary or non-monetary values. If all economic resources needed and the resulting outcomes can be expressed in a common metric (e.g. money), an economic analysis can – in theory – span multiple sectors or take a whole society or multiple societies approach. However, reality is more often such, that multiple outcomes result thereby requiring different metrics and mixed methods, which makes interpretation difficult (Häsler *et al.*, 2014b). Moreover, resources are often not easily divisible and instantly available (Häsler *et al.*, 2012).

Chapter 6 sheds more light on the trade-off between OH complexity and the reductionist approaches of economists. It presents the main concepts and explains the cost-benefit analysis, and other methods that find wide application in health-related studies, i.e. the cost-effectiveness, the cost-utility, and the cost-consequence analysis. Then it summarizes the limitations and challenges of economic evaluation techniques in the context of OH and shows how the economic thought evolved to deal with complex phenomena. Finally, the chapter presents a variety of methods and models, mainly of systemic type, that can contribute to account the diversified and intangible values created by OH initiatives.

3.4.4.3 Select outcomes and metrics

With the OH initiative characterised, the TOC formulated, evaluation rationale and approach selected including relevant outcomes, it will be important to identify metrics suitable to measure the outcomes in question. For disciplinary outcomes, it is recommended to refer to relevant disciplinary literature. Interdisciplinary and OH outcome metrics deemed particularly relevant are described in detail in Chapters 4 to 6. Unexpected outcomes are primarily in the realm of emerging, qualitative information that should be captured through a non-linear impact assessment (Section 3.4.4.2), which we highly recommend as a complement to any other evaluation type. If this information is suited, it may result in new outcomes and metrics to monitor over the remaining time of the initiative.

3.4.5 Review and implementation

Once the evaluation plan is complete, it is recommended to review it carefully with the whole evaluation team and relevant stakeholders to determine whether the rationale, questions, evaluation type, metrics, intended activities, outputs and outcomes are relevant to the target population and the end-user of the evaluation. Moreover, it is advisable to consider if enough resources are available to conduct the evaluation as planned and if there is the relevant capacity. Additionally, it is worthwhile contemplating how the results will be communicated and set aside respective resources and capacity.

Once the evaluation plan has been reviewed and updated (if necessary), the data collection and analyses processes can be implemented. The evaluator must remain involved to monitor data collection as well as the implementation of activities and make sure that the integrity of

data collection stays intact, that appropriate measurement instruments are used, reporting bias and similar is avoided and that the evaluation steps are well coordinated and documented.

3.5 Element 3: assessment of the One Health-ness

Aspects of implementation of initiatives (i.e. the structures, resources, and processes through which delivery is achieved, and the quantity and quality of what is delivered); mechanisms of impact (i.e. how activities, and participants' interactions with them, trigger change); and context (i.e. how external factors influence the delivery and functioning of activities) are examined through process evaluation (Moore *et al.*, 2014, 2015). Process evaluations allow seeing how an initiative develops, its structures, environment and associated activities like communications and marketing. Detailed generic guidelines for process evaluations are available (Anonymous, 2009; Moore *et al.*, 2014, 2015; Saunders, 2005), and provide methods to look at the processes of programme, management and infrastructure together, or, in other words, the capacity of a OH initiative to deliver on its promised outcomes. Critical aspects to be examined are (Moore *et al.*, 2014, 2015):

- Implementation: the structures, resources and processes through which delivery is achieved, and the quantity and quality of what is delivered.
- Mechanisms of impact: how intervention activities, and participants' interactions with them can trigger change.
- Context: how external factors influence the delivery and functioning of interventions. Process evaluations may be conducted within feasibility testing phases, alongside evaluations of effectiveness, or alongside post-evaluation scale-up.

The supplementary online material (ESM-3) contains a table summarising the key characteristics of these guidelines for process evaluation and links them to OH characteristics to facilitate the selection of available guidance. In the following, we describe a set of systematic assessment tools that contribute to a One Health Index (OH-index) as an indicator for the degree of integration of processes in an evaluated initiative.

An implicit characteristic of any OH initiative is its focus on sharing, exchanging, collaborating, learning (from each other), reflecting and generating change across disciplines and sectors in an enabling environment (Rüegg *et al.*, 2017). Consequently, this affects the delivery of an OH initiative (e.g. availability of training, learning about other fields, provision of resources), the mechanisms of impact (e.g. the responses of participants and their interactions with the initiative), and context factors (e.g. shaping of theories on how an initiative works). We refer to the sum of these characteristics as One Health-ness composed of six aspects outlined below and hypothesise that they need to be an integral element of any (process) evaluation in OH. We collate scores and indices that have been suggested in a variety of contexts, adapt them to OH and combine them in a One Health index (OHI) and ratio (OHR) for a holistic appreciation. The six assessment tools have been standardised for use and are made available together with the calculation of the indices and spider diagrams in an Excel workbook for download (ESM-4). Each assessment tool consists of a series of up to 17 questions to be answered and an associated scoring system with values between 0 and 1 as well as spider diagrams. The questions were developed by Working Group 1 of the NEOH

and probe for the specificities of each aspect (outlined below) that can be captured in a semi-quantitative way. They are based on the concept of SMART goals (specific, measurable, achievable, relevant, timely) and wherever appropriate, were adapted from existing evaluation tools. They were then circulated in the NEOH community and revised in several workshops. The scoring recommendations were determined so that scores close to one reflect a high degree of realisation of the different OH characteristics. Here it must be emphasised that the authors do not presume that a high degree of implementation necessarily results in a high impact or effectiveness and underline that at this stage, the benchmark still needs to be established. Each question has the same weight, with exception of the learning assessment, where different levels of organisational learning are weighted according to their level of influence on institutional learning. Consequently, care was taken to balance the number of questions across all assessment tools to provide equal representation in the overall OH-index. The underlying assumption is that each question contains equivalent information to describe the OH initiative. However, because there is no measurable gold standard for each of the questions, the questionnaire and primarily the OH-index and OH-ratio are then assessed for their usefulness and representativeness using case studies as outlined in the overview and a meta-analysis of further published studies. Similar to Element 1, the assessment of the characteristics in this element should ideally be informed by a group of evaluators or (preferably) by relevant stakeholders identified in Element 1.

3.5.1 OH thinking: system thinking and match between context and initiative

OH as a systemic approach with corresponding methodology is of little worth if not based on a foundation of systems thinking (Whitehead *et al.*, 2015). This tool assesses how an OH initiative conceptualises the system in which it operates and in how far it considers features specific to complex adaptive systems. The fundamental idea is that a complex initiative addresses multiple dimensions of the system in which it operates (see Element 1 above). The first set of questions (ESM-4) measure the number of dimensions and the scales within each to gain a semi-quantitative appreciation of the context and the embedded OH initiative. Subsequent questions assess the match between the dimensions of the initiative and its context. Particular attention is given to the scales in different dimensions and whether the initiative reflects the reality of the context in which it operates. A third set of questions probes for concepts and thoughts typically contained in a systems approach (Anderson and Johnson, 1997; Meadows, 2008). To assess systems thinking in written documents, e.g. in a retrospective evaluation or in a proposal, we refer to a method based on statistical semantics proposed by Whitehead and Scherer (2015).

3.5.2 OH planning: cross-sectorial, integrated planning

OH planning is essentially the unfolding of the OH thinking into operational features of the initiative that should facilitate OH working towards achieving the aims and objectives during as well as after the OH initiative. The planning of OH initiatives goes beyond the type of planning that is required for disciplinary and inter-disciplinary projects in which it might be easier to maintain control of what tasks, engagement and resources are required. For instance, OH initiatives typically require human resources with competences in transdisciplinary working methods and excellent communication skills to bridge disciplines and sectors

(Stokols *et al.*, 2013). It is important that the planning includes appropriate methods to engage all of the essential actors and stakeholders, who should be aiming to reach a common goal. Part of the planning evaluation is to assess whether the planned structure, location and timing of the initiative support the OH outcomes aimed for. Due to the complex and trans-domain characteristics of OH challenges, another important aspect of OH initiatives is the ability to self-assess, learn, reflect and adapt to new knowledge and changing conditions, constraints and opportunities over time (Gunderson *et al.*, 2016). Therefore, adaptability features prominently in the evaluation of the planning of OH initiatives. Finally, the planning evaluation helps assessing the tasks and resources allocated to each task employed to achieve the specified objectives of the initiative. The questions in the supplementary online material (ESM-4) were developed to probe if the challenges of complex initiatives described here are addressed in the planning phase and if funding as well as organisational aspects are set up to accommodate adaptive behaviour by the participants. High scores are recommended for a strong support of adaptability and flexibility.

3.5.3 OH working: transdisciplinarity

Interdisciplinary collaboration brings together people with different skills and expertise to tackle complex problems, which often have a high societal stake and require an understanding of the human behaviour (Anonymous, 2005; Hirsch Hadorn *et al.*, 2008; Ledford, 2015). Appreciating potential contributions of multiple disciplines requires examining the limits imposed by a discipline, and rejecting or accepting different disciplinary theories based on their relevance and credibility in order to gain a new understanding about the defined challenge (Lattuca *et al.*, 2012; Nikitina, 2005). In the context of OH, interdisciplinarity has developed towards a participatory approach in the form of transdisciplinarity (Hirsch Hadorn *et al.*, 2008). Both inter- and transdisciplinarity rely on appropriate leadership and management to promote strategic dialogue and shared decision-making (Nancarrow *et al.*, 2013; Strang and McLeish, 2015), which in turn will foster a non-hierarchical relationship between the different disciplines and members within the team. It must also allow for self-reflection, flexibility and recursiveness (Aragrande and Canali, 2015; Hirsch Hadorn *et al.*, 2008; Lélé and Norgaard, 2005; Strang and McLeish, 2015), to be able to challenge and modify underlying assumptions and concepts and thereby enrich understanding. It must be emphasised that such transdisciplinary work demands a high level of commitment and collaboration of all participants to establish personal relationships founded within a climate of trust (Ledford, 2015; Lélé and Norgaard, 2005; Nancarrow *et al.*, 2013). The questions probing for transdisciplinarity (ESM-4) focus on disciplinary diversity, team building and adaptability and were adapted based on the work cited above.

Further aspects of trans- and interdisciplinarity may be assessed, namely for (A) evaluating (academic) participants; and (B) assessing scientific outputs of a OH initiative. However, because individuals may have different roles in an OH initiative, assessing their trans- and interdisciplinary capacity may not always be required or relevant. Also, printed scientific output may not be a primary objective of an OH initiative and occurs with some delay, thereby contributing more to the assessment of outputs than to the implementation per se:

A. The transdisciplinarity of (academic) participants may be assessed based on the interdisciplinarity of publications (see method B) below); interdisciplinarity of teaching, other academic activity (e.g. teaching experience in other disciplines than the own, co-teaching with experts from other disciplines/ sectors, etc.); previous experience with various non-academic communities (e.g. public debate, main stream media, sports and leisure organisations, politics, NGOs, volunteering, etc.); involvement in other disciplinary and interdisciplinary networks (e.g. social and natural science networks other than the own expertise, explicitly interdisciplinary initiatives, science policy, etc.).
B. A framework to evaluate the interdisciplinarity of knowledge production based on citation network analysis can be found here: https://www.mcgill.ca/msr/msr-volume-4/evaluating-knowledge-production-systems. It must be emphasised that this is only represents the written knowledge published in peer reviewed journals, which does not reflect the actual knowledge production occurring in the field.

3.5.4 Systemic organisation: adaptive and shared leadership

In many complex settings, change-oriented leadership has helped to overcome the fallacies of conventions, norms and traditions (Thygeson *et al.*, 2010; Yukl, 2012). Complex systems have leverage points where they can be influenced according to their potential to modify a systems behaviour (Meadows, 2008). The use of these points by an OH initiative determines the dimension(s) and scales at which the initiative is effective. However, in order to be effective, the implementation of the initiative needs to be facilitated by corresponding leadership behaviour. Yukl classifies leadership into four meta-categories with specific objectives (Yukl, 2012): (1) task-oriented behaviour, the primary objective is to accomplish work in an efficient and reliable way; (2) relations-oriented behaviour, the primary objective is to increase the quality of human resources and relations, which is sometimes called 'human capital'; (3) change-oriented behaviour, the primary objectives are to increase innovation, collective learning, and adaptation to the external environment; (4) external leadership behaviour, the primary objectives are to acquire necessary information and resources, and to promote and defend the interests of the team or organisation. These leadership behaviours can be related to the leverage points in a system according to their objectives (Table 3.3).

Yukl emphasises that all leadership behaviours and particularly their flexible applications are relevant for effective leadership. The table simply illustrates that the lack of a particular leadership behaviour may hamper the implementation of a well-conceived OH initiative. The effectiveness of leadership behaviours also depends on the extent to which the leader is trusted by people to be influenced. Most types of leadership behaviours can be used in ethical or unethical ways. Moreover, a leader, who is not trusted because of unethical behaviour will have less influence. Values, namely honesty, altruism, compassion, fairness, courage, and humility may further catalyse effects of good leadership behaviour. In contrast, excessive institutional structure and organisation can nullify these effects (Yukl, 2012). Rooke and Torbert identify further common personality traits of leaders that effectively manage wicked problems: They can challenge the prevailing view without provoking outrage or cynicism; they can act on the big and small picture at the same time, and change course if their chosen path turns

Table 3.3. Ranked list of leverage points at which to intervene in complex systems, from least to most effective, according to Meadows (2008), in relation to leadership behaviour according to Yukl (2012).

Leverage point	**Leadership behaviour**
• Constants, parameters, numbers (such as subsidies, taxes, standards) • The sizes of buffers and other stabilising stocks, relative to their flows. • The structure of material stocks and flows (such as transport networks, population age structures).	Task-oriented leadership: clarifying, planning, monitoring, problem solving
• The lengths of delays, relative to the rate of system change. • The strength of negative feedback loops, relative to the impacts they are trying to correct against. • The gain around driving positive feedback loops. • The structure of information flows (who does and does not have access to information). • The rules of the system (such as incentives, punishments, constraints).	Relation-oriented leadership: supporting, developing, recognising, empowering
• The power to add, change, evolve, or self-organise system structure. • The goals of the system	Change-oriented leadership: Advocating change, envisioning change, encouraging innovation, facilitating collective learning.
• The mindset or paradigm out of which the system (its goals, structure, rules, delays, parameters) arises. • The power to transcend paradigms.	Change-oriented, and external leadership: Networking, external monitoring, representing

out to be incorrect; and they lead with inquiry as well as advocacy, with engagement as well as command, operating all from a deeply held humility and respect for others (Rooke and Torbert, 2005).

A further challenge for leading OH projects is that there may be less interest, commitment, and collaboration if one discipline dominates. Consequently, other disciplines may retract their activity and reinforce the disciplinary silo mentality. To ensure that disciplines are effectively engaged and involved in decision-making from the planning to the implementation stages of projects, shared/distributed leadership and governance should be implemented involving all stakeholders (Houghton *et al.*, 2015; Scott and Caress, 2005).

Consequently, the selection of questions for the systemic organisation of OH initiatives focuses on the structure of teams, as well as management, social and leadership skills of key players and its implementation (ESM-4). The questions were taken from the leadership

assessment tools and the published questionnaires on team work and transdisciplinarity described in Section 3.5.3. High scores were recommended for strong teams, change-oriented leadership skills, clear competences, goals and criteria of success.

3.5.5 Learning infrastructure

Learning is a change in cognition, potential behaviour or actual behaviour through better knowledge and understanding (Fiol and Lyles, 1985; Tsang, 1997). Organisations, such as OH initiatives, learn when they 'encode inferences from history into routines that guide behaviour' (Levitt and March, 1988). This is achieved when discoveries, evaluations and insights by individuals are successfully embedded in the organisation's mental models or cognitive systems and memories (Argyris, 1999). This requires that organisational learning takes into account the learning that takes place at the individual, group, and organisational levels (Giesecke and McNeil, 2004) and the interplay between them (Argyris, 1999). The three levels of learning work together and influence each other and are thus not clearly distinct and mutually exclusive (Redding and Catalanello, 1994). Nevertheless, each level of learning has its characteristics for evaluation.

Individuals can engage in single-loop or double-loop learning. Single-loop learning happens when the output is corrected or existing competences, procedures, technologies and paradigms are improved, without necessarily examining or challenging the underlying beliefs and assumptions. In contrast, double loop learning involves seeing beyond the situation and questioning operating norms. It results in modification of the organisation's underlying norms, policies and objectives.

Individual learning is not a sufficient condition for organisational learning (Gould, 2000). Teams enable the interplay between individual and organisational learning, because they can better share the knowledge (Gould, 2000; Guns, 1998; Watkins and Marsick, 1993) and include more people in the learning process. As a result, team members share awareness of each individual member's expertise, knowledge, and skills, and build a transactive memory system (Stokols *et al.*, 2013). Thus, the evaluation should examine the knowledge shared through teams, to what extent it is shared and how it is shared. The conclusion should show whether the teams provide the appropriate interplay between the individual and the OH initiative. Without supporting the development of a transactive memory system within and across teams, the initiative may have individuals who learn, but it cannot engage in organisational learning (Garvin, 2000). It is important to assess how knowledge is gathered, stored and distributed within a OH initiative (Huysman, 1999), and if and how it provides working environments, technology, rewards, systems, structures, and policies that will support learning (Watkins and Marsick, 1993).

Finally, the context in which the OH initiative is located has influence on the organisational learning (Santa, 2015). The context can be divided in the direct system in which it operates and general environment (Santa, 2014a). The direct system consists of other components with which the initiative interacts, e.g. actors and stakeholders with various relationships. The general environment consists of less specific elements that might affect learning like economic, technological, sociocultural and other factors. The questions probing for learning are taken

from a tool to change organisations towards learning organisations (Santa, 2014b) and focus on the frequency single-loop and double loop learning occur at the level of individuals, teams and the OH initiative, as well as how the system and broader environment support learning (ESM-4).

3.5.6 Sharing infrastructure and processes

In a broad sense, data and information sharing is a catalyser of knowledge generation (Piwowar *et al.*, 2007). Data are often a pre-requisite for the operational gears to function. In OH initiatives, data and information are often the 'raw material' that ultimately will lead to better understanding and a more inclusive and sustainable way of tackling the challenge. If managed appropriately, data and unbiased information sharing can foster trust between participants, as well as minimise misconduct in data management and reporting (Schelling and Zinsstag, 2015; Walter *et al.*, 2007). Additionally, this process can avoid duplication of data collection, ensuring an optimisation of resources (Tenopir *et al.*, 2011).

A central benefit of data sharing is that the data can be analysed to a much greater extent than if only the data owner examines them. This brings benefits to the data owners themselves, as the analysis of others might lead them to further develop their knowledge on the systems the data originated from or the strengths and limitations of their datasets, as well as raising the awareness of the existence of the data in the wider community (Piwowar and Chapman, 2010; Piwowar *et al.*, 2008, 2007). Despite these benefits, data and information sharing often lead to barriers for establishing collaborations (Chokshi *et al.*, 2006) and are hampered by confidentiality issues, time delays and even mistrust in established collaborations. Consequently, data sharing is not as frequent as desirable, and needs to be incentivised to become a natural part of the science and governance cultures. For example, in some countries research relies on a tripartite agreement to share information and collaborate between academia, government institutions and industry, but public access to data may also be reinforced through legislation.

A frequent barrier to data procurement is the bureaucratic process to access data, particularly its complexity and duration. Moreover, fees and technical constraints may arise (Houe *et al.*, 2011), and often too little resources are set aside to for data extraction from databases. Data accessibility and ownership are further critical factors, with data owned by collaborating parties contributing more to knowledge generation than public data or data owned by third parties. Data confidentiality may affect its sharing, as participant consent is usually collected for a specific purpose. This consent might not extend to new studies or alternative purposes, and therefore, security measures may be required to warrant confidentiality. Sharing sensitive data and information within a broader group might entail higher risks for confidentiality breaches (Borgman, 2010). Alternatively, anonymization may reduce that risk, but may also reduce the utility of the data. Finally, it needs to be stressed that knowledge about the data origin and data collection processes is key for the quality and usefulness of stored data, and respective documentation must be available. For example, without knowledge about potential bias throughout the data generating process, it is extremely challenging to merge or combine data from multiple sectors in a OH initiative. The questions in the supplementary online material (ESM-4) derive from a workshop held by NEOH on data and information sharing, in

which critical aspects of data sharing were discussed. High scores are recommended for strong facilitation of sharing. The questions focus on the sharing mechanisms, available resources, data quality and accessibility, storage and the resilience of these to change in the system.

3.5.7 One Health index and ratio

Given the lack of current, commonly accepted benchmarks and the fact that OH initiatives are strongly context specific, it is recommended to assess them in relation to a context specific benchmark. Hence, the evaluator should determine what the perfect situation in the given context would look like (using benchmarking data where they exist) and what proportion of this maximum is achieved with the OH initiative.

The aim of the OHI is to combine the assessments conducted in the previous sections of Element 3. To visualise the six assessments, we suggest a spider diagram (Figure 3.6), in which each assessment is represented by a spoke. The diagram depicts the operational aspects 'OH thinking', 'OH planning' and 'OH working' opposed to the infrastructure for 'learning', 'sharing' and 'systemic organisation'. Thus, the operational aspects on the top left of the diagonal are opposed to the infrastructure on the bottom right. Each spoke is scaled to cover a range of values between 0 and 1. Consequently, the plot not only illustrates the degree of integration by the surface, but it also shows the balance between the operation and the supporting means through its symmetry over the diagonal, numerically represented as the OHR.

In Figure 3.6, two exemplary fictive projects are depicted, an example with real data of a comparison of two OH initiatives can be found in the article by Buttigieg and co-workers (Buttigieg *et al.*, 2018). The fictive Project 1 depicted here has a highly developed transdisciplinary team with a very comprehensive multi-dimensional approach. However, it appears to lack learning and sharing infrastructure and has a mismatch between the

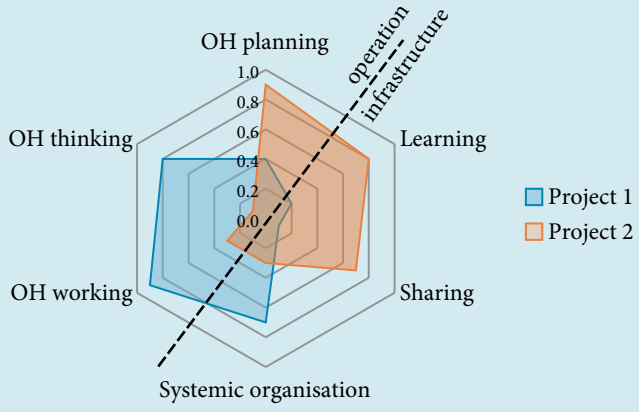

Figure 3.6. Example of the One Health spider diagram for two fictive One Health projects.

responsibilities, authorities and means which affects the transdisciplinary working and hence potentially the OH outcomes. On the other hand, Project 2 has well developed infrastructure and well defined tasks with sufficient funding, but does not explore the inter-disciplinary space nor does it aim at serving multiple species.

The OHI corresponds to the ratio of the surface enclosed by the lines to the surface enclosed if all spokes were equal to 1 (a detailed derivation is provided in the supplementary online material ESM-5). Thus, the OHI is:

$$\mathrm{OHI} = \frac{\{(ScP \times ScT) + (ScL \times ScP) + (ScS \times ScL) + (ScO \times ScS) + (ScW \times ScO) + (ScT \times ScW)\}}{6} \quad (1)$$

where Sc_P is the score obtained in OH planning, Sc_L is the score obtained in learning infrastructure, Sc_S is the score from sharing infrastructure, Sc_O is the score from systemic organisation, Sc_W is the score from OH working, and Sc_T is the score from OH thinking.

The OHR is the relation of the surface covered in the top left of the diagonal to the one in the lower right (a detailed derivation is provided in the supplementary online material ESM-5). To compute the OHR, the surface of the top left surface ($SUR_{operation}$) is calculated:

$$\mathrm{SUR_{Operations}} = \frac{\sqrt{3}}{4}\left\{\left(\frac{\mathrm{ScO} \times \mathrm{ScW}^2}{\mathrm{ScO} + \mathrm{ScW}}\right) + (\mathrm{ScW} \times \mathrm{ScT}) + (\mathrm{ScT} \times \mathrm{ScP}) + \left(\frac{\mathrm{ScP}^2 \times \mathrm{ScL}}{\mathrm{ScP} + \mathrm{ScL}}\right)\right\} \quad (2)$$

and divided by the surface of the lower right ($SUR_{infrastructure}$)

$$\mathrm{SUR_{Infrastructure}} = \frac{\sqrt{3}}{4}\left\{\left(\frac{\mathrm{ScP} \times \mathrm{ScL}^2}{\mathrm{ScP} + \mathrm{ScL}}\right) + (\mathrm{ScL} \times \mathrm{ScS}) + (\mathrm{ScS} \times \mathrm{ScO}) + \left(\frac{\mathrm{ScO}^2 \times \mathrm{ScW}}{\mathrm{ScO} + \mathrm{ScW}}\right)\right\} \quad (3)$$

resulting in the following equation:

$$\mathrm{OHR} = \frac{\left(\frac{\mathrm{ScO} \times \mathrm{ScW}^2}{\mathrm{ScO} + \mathrm{ScW}}\right) + (\mathrm{ScW} \times \mathrm{ScT}) + (\mathrm{ScT} \times \mathrm{ScP}) + \left(\frac{\mathrm{ScP}^2 \times \mathrm{ScL}}{\mathrm{ScP} + \mathrm{ScL}}\right)}{\left(\frac{\mathrm{ScP} \times \mathrm{ScL}^2}{\mathrm{ScP} + \mathrm{ScL}}\right) + (\mathrm{ScL} \times \mathrm{ScS}) + (\mathrm{ScS} \times \mathrm{ScO}) + \left(\frac{\mathrm{ScO}^2 \times \mathrm{ScW}}{\mathrm{ScO} + \mathrm{ScW}}\right)} \quad (4)$$

3.6 Element 4: compare and develop recommendations

3.6.1 Compare the One Health-ness to the achieved outcomes

One of the aims of the NEOH framework is to be able to assess the 'value added' by One Health. The underlying question is therefore how the promoted integrated and interdisciplinary processes affect the project outcomes. Using a TOC model allows evaluating both, the processes and the outcomes concurrently. In the NEOH TOC model the processes refer to the One Health-ness metrics and the outcomes to the success or failures of a particular OH initiative. Evaluating both processes and outcomes allows multiple advantages compared to just assessing outcomes (De Silva *et al.*, 2014), these are:

1. Ability to differentiate between an initiative that failed because the process was flawed and an initiative that failed because the processes were not satisfactorily carried out.

2. Ability to determine which pathways are most effective at causing the desired outcomes and which are critical for future project success.
3. Ability to identify how the context, i.e. the environment in which the project is being conducted, affects the TOC and thus the outcomes.
4. Ability to identify unexpected outcomes and hypothesise why these occurred.

An additional advantage is the ability to identify and assess intermediate outcomes that can be used as markers of success if the evaluation activities will have ended by the time of the final outcomes (Rogers, 2014). This is particularly important for complex interventions with very long-term goals.

There are a variety of ways to assess the processes and outcomes, which include standard quantitative and qualitative study designs. Used correctly, any study method can be used to measure one or more process(es) or outcome(s). For complete project evaluation every process and outcome should be measured by at least one study; however, if this is not possible the key processes and outcomes must be identified and measured. More advanced statistical modelling methods can also be used and these have the advantage of being able to look at interactions between the metrics. These techniques include: structural equation modelling, discrete simulation models, agent-based modelling, system dynamics modelling, and comparative qualitative analysis. These are described in greater detail in Table 3.4 along with a presentation of their pros and cons.

3.6.2 Develop recommendations

The observations made during the evaluation must now be translated into constructive feedback for the concerned parties. At this science-policy interface careful communication is essential - especially when health is concerned, communication can be a sensitive issue for many involved. Often (external) communication beyond the research or policy institution(s), is merely taken seriously at a later stage, when most developments have taken shape and crucial decisions were made. In the context of OH, we consider communication as a key part of the whole process, from start to finish. We refer to experiences in the field of risk communication, which largely developed around health risks related to environmental issues like nuclear power incidents and the vast diversity of pollutants that we are exposed to. We also propose to frame communication in relation to more than 'just' outcomes, and consider it as decision support: helping receivers of information to make up their own mind about the issue depending on their own stakes, perceptions and preferences, in a well-informed manner, as well as well-argued transparency about key choices involved.

3.6.2.1 A brief history of risk communication

Risk communication has evolved from one-way communication, restricted to the dissemination of information from experts to the public, to two-way risk communication, with a focus on participation and cooperation between scientists, policy-makers and the public (Fischhoff, 1995; Leiss, 1996; McComas, 2006). One-way communication has often been based on the 'deficit model' (Wynne, 1996), i.e. the assumption that clear communication of objective and sound scientific information from experts to the 'ignorant' public is sufficient to make them aware of problems and respond accordingly. However, in most cases, the science is not simple

Table 3.4. A description of some of the advanced statistical modelling techniques available for evaluating processes and outcomes and their pros and cons.

Modelling technique Description	Pros	Cons
Structural equation modelling (SEM) – Nachtigall *et al.*, 2003		
SEM is an umbrella term for multiple modelling techniques. The technique allows the modeller to conduct and combine the techniques of factor analysis, multiple regression analysis, ANOVA, and others. It is able to estimate multiple and interrelated dependence in a single analysis.	• Very flexible as it deals with a system of regression equations (rather than single/multiple linear regression) • Newer software makes this technique now accessible to inexperienced modellers. • Possibility of modelling complex dependencies and latent variables	• Complicated and difficult to understand • Large amount of data required • Sample size requirements often vague • The models are not necessarily assessments of causality • Context can be neglected • The ease of producing a model with new user-friendly interface software means that inexperienced modellers use it but produce statistically flawed models
Discrete event simulation (DES) models – Allen *et al.*, 2015; Caro *et al.*, 2016		
The system is modelled as a series of events that occur over time, individuals can be assigned information and their progress modelled through time. Resources can also be accounted for.	• DES allows for complex decision logic that is not readily available in other modelling techniques • Can be used to test 'what if?' scenarios	• Stochastic approach means that the model output changes slightly each time it is run • Is still a measure of population behaviour not individual but this is often misunderstood as 'entities' represent people with their corresponding attributes
Agent-based modelling – Loomis *et al.*, 2008; Schank, 2010; Siebers, 2013		
A system is modelled as a collection of autonomous decision-making entities ('agents'). Each agent makes a series of decisions based on assigned rules, attributes, and their interactions with their environment and each other. Best for heterogeneous, autonomous, pro-active actors e.g. human-centred systems	• Can allow for complex agent behaviour such as that influenced by memory and motivations. • Can demonstrate individual agents behaviour, not just population behaviour.	• Ability to code is usually needed, languages such as Java are used • Many programmes do not have sufficient power for very complex systems • Models are difficult to validate as the agent-based nature means outputs are not testable with standard statistical techniques

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Table 3.4. Continued.

Modelling technique Description	Pros	Cons
System dynamics modelling – Pitman *et al.*, 2012; Sterman, 2001		
Computer simulation and modelling technique that allows for framing, understanding, and discussing complex issues and problems. Structure is as important as the components of the model.	• Good ability to take into account indirect effects in system • Ability to incorporate time delays, outcomes that are distant in space and time to their cause, and multicausality • Good for identifying causal factors	• Inevitably some components of the complex system will have to be estimated
Qualitative comparative analysis (QCA) – Marshall, 2016		
QCA is a method to analyse the causal contribution of different conditions to an outcome. This method bridges qualitative and quantitative analysis. It is able to handle causal complexity.	• Allows for investigation of multicausality	• Works best on small sample sizes

and consensual, but involves ambiguities and uncertainties. Also the public is more than a mere recipient of information, but consists of actors in the decision process of the strategies to improve and/or preserve situations and in the management of the risks.

3.6.2.2 Communication about complexity

An important challenge in risk communication is how to exchange meaningfully information regarding uncertain, complex and ambiguous knowledge (Renn, 2008). As outlined earlier, framing and dealing with complexity is of crucial importance in OH science, policy and practice (Keune and Assmuth, in press). The number and diversity of factors that may play a role in an OH issue are enormous, and these issues have also a multitude of characteristics and consequences. Framing this complexity is crucial because it sets the boundaries of the system in which the OH initiative is situated in terms of thoughts and actions. This is not merely a technical process of scientific framing, but also a methodological decision-making process with both scientific and societal implications. Mostly the benefits and risks related to such issues cannot be generalized or objectified, and will be distributed unevenly, resulting in health and environmental inequalities. Even more generally, framing is crucial as it reflects cultural factors and historical contingencies, perceptions and mind-sets, political processes,

associated values and world-views. Framing is at the core of how we as humans relate to and deal with human, animal and ecosystem health, as scientists, policy makers and practitioners, with models, policies or actions.

The two core issues in risk communication are: 'How can science formulate confident, robust and clear messages when it struggles with uncertainties, unknowns, and ambiguities due to complexity?' and 'How does the traditional scientific evidence base approach live up to expectations of clear communication and of solving problems without pleading for endless ever more detailed research and without too complicated messages due to lack of clear cut scientific understanding?'. The argument that communication should be restricted because of uncertainties is challenged by various authors. Ragas and co-workers (2006) argue that if the information is used by regulators, public managers and risk assessors, then the public equally ought to know. Others dispute the belief that the public is unable to deal with complex issues (e.g. (Marris *et al.*, 2001)), and a third group has shown that withholding data regarding uncertainty often reduces trust (Frewer, 2004; Van Kleef *et al.*, 2007). Hence, as Slovic (1998) has stated, 'The challenge is to communicate the risk estimates so that they are understandable and that the risks and associated uncertainty can be put into a personal perspective'.

3.6.2.3 Communication to support decision making

Framing communication as decision support in a OH context means to inform end-users about relevant elements of complexity in an inclusive, well-structured manner, not as an end-point, but as a basis for end-user decision making about what to do. Decision support methods (Marakas, 1999) can be employed in semi-structured or unstructured decision contexts, can provide support to either an individual or a group, and facilitate learning on the part of the decision maker(s). They are meant to be interactive and user-friendly, and generally are developed in an evolutionary iterative process, using relevant data and models. Multi-criteria decision analysis (MCDA) is a good example of such decision support regarding complex issues: it can simultaneously embrace, combine, and structure various types of often incommensurable diversity: diversity of information (e.g. qualitative and quantitative data, as well as uncertainty), diversity of opinions (among experts), diversity in actor perspectives (stakes) as well as diversity in assessment/decision-making criteria (Keune, 2013). MCDA is not a miracle tool that will objectively solve all problems by unambiguously calculating what is best. It functions more like a 'sounding board': it will structure and visualize the input of actors and factors involved. As such it will offer a basis for well informed and transparent reflection, learning and deliberation. Also, it helps users to be transparent about the decision choices they make, about what they take into account, their preferences and underlying argumentations.

3.6.2.4 Communication is a serious concern

Despite advances in theory and numerous initiatives in practice, the deficit model continues to dominate many attitudes towards the public communication of science (Davies, 2008) as well as practices. Two-way communication is seen as inherently difficult and dangerous. The alternative view – that two-way communication helps to make scientists and policy makers accountable and to empower the public – remains a rarity in many fields of science and policy. Much remains to be done to devise and promote more open, yet workable solution oriented approaches to the communication of science, risk and policy, in the context of complexity.

The epistemological divide between the traditional and alternative approaches largely relies on ambassadors safeguarding their own approach. Without ambassadors of diverse paradigms at the table where crucial methodological choices are being made, especially in practice, under resource constraints and time pressure, the dominant approach will largely steer the process. This also does not imply that traditional experts are not open to alternative approaches or that they do not see the value of it. But in practice, the initial open arms attitude towards two-way communication often is accompanied by closed mind-sets amongst the traditional experts as the process progresses. There may be some exceptional transdisciplinary personalities, but in many settings of real practice the shift to a more collaborative approach often does not easily survive without social scientists being effectively involved. To implement OH it is therefore crucial that the diversity which is considered to be relevant in the process is represented by ambassadors at the epistemological and methodological decision table. This requires including risk communication experts in order to facilitate two-way directional and problem solving collaborations.

Acknowledgements

This chapter is based upon work from COST Action 'Network for Evaluation of One Health' (TD1404), supported by COST (European Cooperation in Science and Technology).

References

Allen, M., Spencer, A., Gibson, A., Matthews, J., Allwood, A., Prosser, S. and Pitt, M., 2015. Right cot, right place, right time: improving the design and organisation of neonatal care networks – a computer simulation study. Health Serv Deliv Res 3(20).

Anderson, V. and Johnson, L., 1997. Systems thinking basics: from concepts to causal loops. Leverage Networks Inc., Acton, MA, USA.

Anonymous, 1999. Interactive terminology for Europe. Available at: https://tinyurl.com/pqlebur.

Anonymous, 2005. In praise of soft science. Nature 435: 1003.

Anonymous, 2009. Developing process evaluation questions. Centers for Disease Control and Prevention Evaluation Briefs. Available at: https://tinyurl.com/y7we4v2p.

Aragrande, M. and Canali, M., 2015. An operational tool to enhance One Health interdisciplinarity. In: Proceedings 3rd GRF One Health Summit. October 4-7, 2015. Davos, Switzerland.

Argyris, C., 1999. On organizational learning, 2nd edition. Wiley-Blackwell, Oxford, UK.

Baum, S.E., Machalaba, C., Daszak, P., Salerno, R.H. and Karesh, W.B., 2016. Evaluating one health: are we demonstrating effectiveness? One Health 3: 5-10.

Befani, B., Ramalingam, B. and Stern, E., 2015. Introduction – towards systemic approaches to evaluation and impact. IDS Bull 46(1): 1-6.

Borgman, C.L., 2010. Scholarship in the digital age: information, infrastructure, and the internet. MIT Press, Cambridge, MA, USA.

Boriani, E., Esposito, R., Frazzoli, C., Fantke, P., Hald, T. and Rüegg, S.R., 2017. Framework to define structure and boundaries of complex health intervention systems: the ALERT project. Front Publ Health 5: 182.

Britt, H., 2016. Discussion note: complexity-aware monitoring. USAID, Washington, DC, USA.

Brown, A.-M., 2016. Differences between the theory of change and the logic model. Available at: https://tinyurl.com/y8tqyx3g.

Bunge, M., 1960. Levels: a semantical preliminary. Rev Metaphys 13: 396-406.

Buttigieg, S.C., Savic, S., Cauchi, D., Lautier, E., Canali, M. and Aragrande, M., 2018. Brucellosis control in Malta and Serbia: a One Health evaluation. Front Vet Sci 5: 147.

Caro, J.J.J., Möller, J. and Moller, J., 2016. Advantages and disadvantages of discrete-event simulation for health economic analyses. Expert Rev Pharmacoecon Outcomes Res 16: 327-329.

Chigas, D., Ehlinger, T., Befani, B., Docherty, J., Michaels, J., Smith, R., Walker, T. and Yoshida, R., 2014. Non-linear impact assessment: challenges, approaches and tools. Dynamical Systems Innovation Lab, Honolulu, Hawai'i.

Chokshi, D.A., Parker, M. and Kwiatkowski, D.P., 2006. Data sharing and intellectual property in a genomic epidemiology network: policies for large-scale research collaboration. Bull World Health Organ 84: 382-387.

Ciborra, C.U. and Hanseth, O., 1998. From tool to Gestell – agendas for managing the information infrastructure. Inf Technol People 11: 305-327.

Commission on Social Determinants of Health of the WHO, 2008. Social determinants of health report: closing the gap in a generation. World Health Organisation, Geneva, Switzerland.

Craig, P., Dieppe, P., Macintyre, S., Michie, S., Nazareth, I. and Petticrew, M., 2013. Developing and evaluating complex interventions: the new Medical Research Council guidance. Int J Nurs Stud 50: 587-592.

Davies, R. and Dart, J., 2005. The Most Significant Change (MSC) technique. CARE International, Genève, Switzerland.

Davies, S.R., 2008. Constructing communication. Sci Commun 29: 413-434.

De Silva, M.J., Breuer, E., Lee, L., Asher, L., Chowdhary, N., Lund, C. and Patel, V., 2014. Theory of change: a theory-driven approach to enhance the Medical Research Council's framework for complex interventions. Trials 15: 267.

Dellinger, M., Tofan, L. and Ehlinger, T., 2012. Predictive analytics and pattern visualisation for human health. Risk Assessm 2197: 2186-2197.

Deprez, S., 2014. The 5 key assumptions of outcome mapping. Available at: https://tinyurl.com/y8bt5f78.

Falzon, L.C., Lechner, I., Chantziaras, I., Collineau, L., Courcoul, A., Filippitzi, M.-E., Laukkanen-Ninios, R., Peroz, C., Pinto Ferreira, J., Postma, M., Prestmo, P.G., Phythian, C.J., Sarno, E., Vanantwerpen, G., Vergne, T., Grindlay, D.J.C. and Brennan, M.L., in press. Quantitative outcomes of a One Health approach to study global health challenges. Ecohealth. https://doi.org/10.1007/s10393-017-1310-5.

Food and Agriculture Organisation (FAO), 2013. The state of food and agriculture. FAO, Rome, Italy.

Fath, B.D., Dean, C.A. and Katzmair, H., 2015. Navigating the adaptive cycle: an approach to managing the resilience of social systems. Ecol Soc 20(2): 24.

Fiol, M.C. and Lyles, M.A., 1985. Organizational learning. Acad Manag Rev 10: 8003-8013.

Fischhoff, B., 1995. Risk perception and communication unplugged: twenty years of process 1. Risk Anal 15: 137-145.

Fonseca, A.G., Torgal, J., De Meneghi, D., Gabriël, S., Coelho, A.C. and Vilhena, M., 2018. One Health-ness evaluation of cysticercosis surveillance design in Portugal. Front Public Health 6: 74.

Frewer, L., 2004. The public and effective risk communication. Toxicol Lett 149: 391-397.

Garcia, J.R. and Zazueta, A., 2015. Going beyond mixed methods to mixed approaches: a systems perspective for asking the right questions. IDS Bull 46: 30-43.

Garvin, D.A., 2000. Learning in action: a guide to putting the learning organization to work. Harward Business Press, Boston, MA, USA.

Gertler, P.J., Martinez, S., Premand, P., Rawlings, L.B. and Vermeersch, C.M.J., 2011. Impact evaluation in practice. World Bank Publications. Available at: https://tinyurl.com/y8c3k6fj.

Giesecke, J. and McNeil, B., 2004. Transitioning to the learning organization. Libr Trends 53: 54.

Gold, J., Wilson-Grau, R., Fisher, S., Roberts, D. and Otoo, S., 2014. Cases in outcome harvesting. Worldbank, Washington, DC, USA.

Gould, N., 2000. Becoming a learning organisation: a social work example. Soc Work Educ 19: 585-596.

Gunderson, L.H., Cosens, B. and Garmestani, A.S., 2016. Adaptive governance of riverine and wetland ecosystem goods and services. J Environ Manag 183: 353-360.

Guns, B., 1998. The faster learning organization, 1st edition. Jossey-Bass, New York, NY, USA.

Hanin, M.C.E., Queenan, K., Savic, S., Karimuribo, E., Rüegg, SR. and Häsler, B., 2018. A One Health evaluation of the Southern African Centre for Infectious Disease Surveillance. Front Vet Sci 5: 33.

Häsler, B., Cornelson, L., Bennani, H. and Rushton, J., 2014a. A review of the metrics for One Health benefits. Rev Sci Tech Off Int Epiz 33: 453-464.

Häsler, B., Gilbert, W., Jones, B.A., Pfeiffer, D.U., Rushton, J. and Otte, M.J., 2012. The economic value of One Health in relation to the mitigation of zoonotic disease risks world organisation for animal health. Curr Top Microbiol Immunol 365: 127-151.

Häsler, B., Hiby, E., Gilbert, W., Obeyesekere, N., Bennani, H. and Rushton, J., 2014b. A One Health framework for the evaluation of rabies control programmes: a case study from Colombo City, Sri Lanka. PLoS Negl Trop Dis 8(10): e3270.

Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, D., Grossenbacher-Mansuy, S., Joye, W., Pohl, C., Wiesmann, U. and Zemp, E., 2008. Handbook of transdisciplinary research, 1st edition. Springer International Publishing AG, Cham, Switzerland.

Houe, H., Gardner, I.A. and Nielsen, L.R., 2011. Use of information on disease diagnoses from databases for animal health economic, welfare and food safety purposes: strengths and limitations of recordings. Acta Vet Scand 53, Suppl. 1: S7.

Houghton, J.D., Pearce, C.L., Manz, C.C., Courtright, S. and Stewart, G.L., 2015. Sharing is caring: toward a model of proactive caring through shared leadership. Hum Resour Manag Rev 25: 313-327.

Huysman, M., 1999. Balancing biases: a critical review of the literature on organizational learning. In: Easterby-Smith, M., Araujo, L. and Burgoyne, J.G. (eds.) Organizational learning and the learning organization: developments in theory and practice. SAGE Publications, London, UK, pp. 59-74.

Ifejika Speranza, C., Wiesmann, U. and Rist, S., 2014. An indicator framework for assessing livelihood resilience in the context of social – ecological dynamics. Glob Environ Change 28: 109-119.

Ingram, J. and White, R., 2015. Inaugural lecture – food systems: challenges, concepts and communities. Available at: https://tinyurl.com/yak7cmeu.

INTRAC, 2015. Outputs, outcome and impact. Available at: https://tinyurl.com/y7utlrgh.

Jones, K.E., Patel, N.G., Levy, M.A., Storeygard, A., Balk, D., Gittleman, J.L. and Daszak, P., 2008. Global trends in emerging infectious diseases. Nature 451: 990-994.

Keune, H., 2013. Negotiated complexity: framing multi-criteria decision support in environmental health practice. Am J Oper Res 3: 153-166.

Keune, H., Assmuth, T., in press. Framing complexity in environment and human health. In: Oxford research encyclopedia of environmental science. Oxford University Press, New York, NY, USA. Available at:http://tinyurl.com/yamqsk45.

Khanal, P. and Bhattarai, N., 2016. Health beyond health to bridge the global health gap. Lancet Glob Health 4: e792.

Laing, G., Aragrande, M., Canali, M., Savic, S. and De Meneghi, D., 2018. Control of cattle ticks and tick-borne diseases by acaricide in southern province of Zambia: a retrospective evaluation of animal health measures according to current one health concepts. Front Public Health 6: 45.

Lang, D.J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M. and Thomas, C.J., 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustain Sci 7: 25-43.

Lang, T. and Rayner, G., 2012. Ecological public health: the 21st century's big idea? An essay by Tim Lang and Geof Rayner. BMJ 345: e5466-e5466.

Lattuca, L.R., Knight, D.B. and Bergom, I.M., 2012. Developing a measure of interdisciplinary competence for engineers. In: Conference Proceedings 2012 of the American Society for Engineering Education, pp. 1-19. Available at: https://tinyurl.com/yc9k6beb.

Ledford, H., 2015a. How to solve the world's biggest problems. Nature 525: 308-311.

Léger, A., Stärk, K., Rushton, J. and Nielsen, L.R., 2018. A One Health evaluation of the University of Copenhagen research centre for control of antibiotic resistance. Front Vet Sci, https://doi.org/10.3389/fvets.2018.00194.

Leiss, W., 1996. Three phases in the evolution of risk communication practice. Ann Am Acad Pol Soc Sci 545: 85-94.

Lélé, S. and Norgaard, R.B., 2005. Practicing interdisciplinarity. Bioscience 55: 967.

Lerner, H. and Berg, C., 2015. The concept of health in One Health and some practical implications for research and education: what is One Health? Infect Ecol Epidemiol 5: 25300.

Levitt, B. and March, J.G., 1988. Organizational learning. Ann Rev Sociol 14: 319-340.

Loomis, J., Bond, C. and Harpman, D., 2008. The potential of Agent-Based modelling for performing economic analysis of adaptive natural resource management. J Nat Resour Policy Res 1: 35-48.

Manolakos, E., Virani, H. and Novotny, V., 2007. Extracting knowledge on the links between the water body stressors and biotic integrity. Water Res 41: 4041-4050.

Marakas, G.M., 1999. Decision Support Systems in the 21st century. Pearson Education, Hoboken, NJ, USA.

Marris, C., Wynne, B., Simmons, P. and Weldon, S., 2001. Public perceptions of agricultural biotechnologies in Europe. PABE, Brussels, Belgium. Available at: http://csec.lancs.ac.uk/archive/pabe/.

Marshall, G., 2016. Qualitative comparative analysis. Better Evaluation. Available at: https://tinyurl.com/y9h6xhu4.

McComas, K.A., 2006. Defining moments in risk communication research: 1996-2005. J Health Commun 11: 75-91.

Meadows, D.H., 2008. Thinking in systems – a primer. Chelsea Green Publishing Co, White River Junction, VT, USA.

Moore, G., Audrey, S., Barker, M. and Bond, L., 2014. Process evaluation of complex interventions. UK Medical Research Council (MRC) guidance, Southampton, UK.

Moore, G.F., Audrey, S., Barker, M., Bond, L., Bonell, C., Hardeman, W., Moore, L., O'Cathain, A., Tinati, T., Wight, D. and Baird, J., 2015. Process evaluation of complex interventions: Medical Research Council guidance. BMJ 350: h1258.

Mowles, C., 2014. Complex, but not quite complex enough: the turn to the complexity sciences in evaluation scholarship. Evaluation 20: 160-175.

Muñoz-Prieto, A., Nielsen, L.R., Martinez-Subiela, S., Mazeikiene, J., Lopez Jornet, P.L., Savic, S. and Tvarijonaviciute, A., 2018. Evaluation of One Health operations and supporting infrastructure in a questionnaire-based study of obesity among dogs and their owners in 11 European countries. Front Vet Sci 5: 163.

Nachtigall, C., Kroehne, U., Funke, F. and Steyer, R., 2003. (Why) should we use SEM? Pros and cons of structural equation modeling. Methods Psychol Res 8: 1-22.

Nancarrow, S.A., Booth, A., Ariss, S., Smith, T., Enderby, P. and Roots, A., 2013. Ten principles of good interdisciplinary team work. Hum Resour Health 11: 19.

Nikitina, S., 2005. Pathways of interdisciplinary cognition. Cogn Instr 23: 389-425.

Novotny, V., Bartošová, A., O'Reilly, N. and Ehlinger, T., 2005. Unlocking the relationship of biotic integrity of impaired waters to anthropogenic stresses. Water Res 39: 184-198.

Ostrom, E., 2009. A general framework for analyzing sustainability of social-ecological systems. Science 325: 419-422.

Paternoster, G., Tomassone, L., Tamba, M., Chiari, M., Lavazza, A., Piazzi, M., Favretto, A.R., Balduzzi, G., Pautasso, A. and Vogler, B.R., 2017. The degree of One Health implementation in the West Nile virus integrated surveillance in northern Italy, 2016. Front Publ Health 5: 1-10.

Pfeiffer, D.U., 2014. From risk analysis to risk governance – adapting to an ever more complex future. Vet Ital 50: 169-176.

Pitman, R., Fisman, D., Zaric, G.S., Postma, M., Kretzschmar, M., Edmunds, J. and Brisson, M., 2012. Dynamic transmission modeling: a report of the ISPOR-SMDM modeling good research practices task force-5. Val Health 15: 828-834.

Piwowar, H.A., Becich, M.J., Bilofsky, H. and Crowley, R.S., 2008. Towards a data sharing culture: recommendations for leadership from academic health centers. PLoS Med 5: 1315-1319.

Piwowar, H.A. and Chapman, W.W., 2010. Public sharing of research datasets: a pilot study of associations. J Informetr 4: 148-156.

Piwowar, H.A., Day, R.S. and Fridsma, D.B., 2007. Sharing detailed research data is associated with increased citation rate. PLoS ONE 2(3): e308.

Pumain, D., Pavé, A., Venant, Fa., Verdier, N., Victorri, B. and West, G.B., 2006. Hierarchy in natural and social sciences, 1st edition. Springer, Dordrecht, the Netherlands.

Rabinowitz, P.M., Kock, R., Kachani, M., Kunkel, R., Thomas, J., Gilbert, J., Wallace, R., Blackmore, C., Wong, D., Karesh, W., Natterson, B., Dugas, R. and Rubin, C., 2013. Toward proof of concept of a one health approach to disease prediction and control. Emerg Infect Dis 19: e130265.

Radeski, M., O'Shea, H., De Meneghi, D. and Ilieski, V., 2018. Positioning animal welfare in the One Health concept through evaluation of an animal welfare center in Skopje, Macedonia. Front Vet Sci 4: 1-11.

Ragas, A.M.J., Huijbregts, À.M.A.J., Van Kaathoven, À.E.H., Wolsink, J.H. and Wemmenhove, J., 2006. Development and implementation of a right-to-know web site that presents estimated cancer risks for air emissions of large industrial facilities. Integr Environ Assess Manag 2(4): 365-374.

Rayner, G. and Lang, T., 2012. Ecological public health. Reshaping the conditions for good health. Routledge, Abingdon, UK.

Redding, J.C. and Catalanello, R.F., 1994. Strategic readiness: the making of the learning organization. Jossey-Bass, San Francisco, CA, USA.

Renn, O., 2008. Risk governance: coping with uncertainty in a complex world. Earthscan, London, UK.

Retief, F., Bond, A., Pope, J., Morrison-Saunders, A. and King, N., 2016. Global megatrends and their implications for environmental assessment practice. Environ Impact Assess Rev 61: 52-60.

Reynolds, M., 2015. (Breaking) the iron triangle of evaluation. IDS Bull 46: 71-86.

Rogers, P.J., 2014. Theory of change (Unicef), methodological briefs: impact evaluation. Unicef, Firenze, Florence, Italy.

Romanelli, C., Cooper, D., Campbell-Ledrum, D., Maiero, M., Karesh, W.B., Danny, H. and Golden, C.D., 2015. Connecting global priorities : biodiversity and human health - a state of knowledge review. WHO, Geneva, Switzerland.

Rooke, D. and Torbert, W.R., 2005. Seven transformations of leadership. Harv Bus Rev. Available at: https://tinyurl.com/p5vmhhh.

Rüegg, S., Rosenbaum Nielsen, L., Buttigieg, S., Santa, M., Aragrande, M., Canali, M., Ehlinger, T., Chantziaras, I., Boriani, E., Radeski, M., Bruce, M. and Häsler, B., 2018. A systems approach to evaluate One Health initiatives. Front Vet Sci 5: 23.

Rüegg, S.R., McMahon, B.J., Häsler, B., Esposito, R., Nielsen, L.R., Ifejika Speranza, C., Ehlinger, T., Peyre, M., Aragrande, M., Zinsstag, J., Davies, P., Mihalca, A.D.A., Buttigieg, S.C., Rushton, J., Carmo, L.P., De Meneghi, D., Canali, M., Filippitzi, M.-E.M.E., Goutard, F.L., Ilieski, V., Milićević, D., O'Shea, H., Radeski, M., Kock, R., Staines, A., Lindberg, A., Rosenbaum Nielsen, L., Ifejika Speranza, C., Ehlinger, T., Peyre, M., 2017. A blueprint to evaluate One Health. Front Public Health 5: 1-5.

Rushton, J., Häsler, B., De Haan, N. and Rushton, R., 2012. Economic benefits or drivers of a 'One Health' approach: why should anyone invest? Onderstepoort J Vet Res 79: 1-5.

Santa, M., 2014a. Framework for multivariate continuous transformation towards learning organization. University Paris 1 Pantheon, Sorbonne, Paris, France.

Santa, M., 2014b. The learning organization atlas framework. Available at: http://tinyurl.com/yah5glgu.

Santa, M., 2015. Learning organisation review – a 'good' theory perspective. Learn Organ 22: 242-270.

Saunders, R.P., 2005. Developing a process-evaluation plan for assessing health promotion program implementation: a how-to guide. Health Promot Pract 6: 134-147.

Schank, J., 2010. Agent-based modeling. Available at: https://tinyurl.com/zvwp2gb.

Schelling, E. and Zinsstag, J., 2015. Transdisciplinary research and One Health. In: Zinsstag, J., Schelling, E., Waltner-Toews, D., Whittaker, M. and Tanner, M. (eds.) One Health: the theory and practice of integrated health approaches. CABI, Wallingford, UK, pp. 366-373.

Scott, L. and Caress, A.-L., 2005. Shared governance and shared leadership: meeting the challenges of implementation. J Nurs Manag 13: 4-12.

Siebers, P.-O., 2013. Simulation in a nutshell. Available at: https://tinyurl.com/yapycd3j.

Slovic, P., 1998. The risk game. Science 59: 73-77.

Sterman, J.D., 2001. System dynamics modeling: tools for learning in a complex world. Calif Manage Rev 43: 8-25.

Stern, E., 2015. Impact evaluation. a guide for commissioners and managers. Bond, London, UK, 35 pp. Available at: http://tinyurl.com/yby7kcvy.

Stokols, D., Fuqua, J., Gress, J., Harvey, R., Phillips, K., Baezconde-Garbanati, L., Unger, J., Palmer, P., Clark, M.A., Colby, S.M., Morgan, G. and Trochim, W., 2003. Evaluating transdisciplinary science. Nicotine Tob Res 5: 21-39.

Stokols, D., Hall, K.L. and Vogel, A.L., 2013. Transdisciplinary public health: definitions, core characteristics and strategies for success. In: Haire-Joshu, D. and McBride, T.D. (eds.) Transdisciplinary public health: reserach, methods and practice. Jossey-bass Publishers, San Francisco, CA, USA, pp. 3-30.

Strang, V. and McLeish, T., 2015a. Evaluating interdisciplinary research: a practical guide. Durham University, Durham, UK, 20 pp.

Taplin, D.H., Clark, H., Collins, E. and Colby, D.C., 2013. Theory of change. Technical papers: a series of papers to support development of theories of change based on practice in the field. ActKnowledge, New York, NY, USA, 23 pp.

Tenopir, C., Allard, S., Douglass, K., Aydinoglu, A.U., Wu, L., Read, E., Manoff, M. and Frame, M., 2011. Data sharing by scientists: practices and perceptions. PLoS ONE 6: 1-21.

Thygeson, M., Morrissey, L. and Ulstad, V., 2010. Adaptive leadership and the practice of medicine: a complexity-based approach to reframing the doctor-patient relationship. J Eval Clin Pract 16: 1009-1015.

Trochim, W.M., Cabrera, D.A., Milstein, B., Gallagher, R.S. and Leischow, S.J., 2006. Practical challenges of systems thinking and modeling in public health. Am J Public Health 96: 538-546.

Tsang, E.W.K., 1997. Organizational learning and the learning organization: a dichotomy between descriptive and prescriptive research. Hum Relations 50: 73-89.

Van Kleef, E., Houghton, J.R., Krystallis, A., Pfenning, U., Rowe, G., Van Dijk, H., Van der Lans, I.A. and Frewer, L.J., 2007. Consumer evaluations of food risk management quality in Europe. Risk Anal 27: 1565-1580.

Wallace, R.G. and Wallace, R., 2016. Neoliberal Ebola. Springer International Publishing, Cham, Switzerland.

Walter, A.I., Helgenberger, S., Wiek, A. and Scholz, R.W., 2007. Measuring societal effects of transdisciplinary research projects: design and application of an evaluation method. Eval Program Plann 30: 325-338.

Ward, M.P. and Lewis, F.I., 2013. Bayesian graphical modelling: applications in veterinary epidemiology. Prev Vet Med 110: 1-3.

Watkins, K.E. and Marsick, V.J., 1993. Sculpting the learning organization: lessons in the art and science of systemic change, 1st edition. Jossey-Bass, San Francisco, CA, USA.

Whitehead, N.P. and Scherer, W.T., 2015. Quantifying the quality of a systems approach. In: 2015 Annual IEEE Systems Conference (SysCon) Proceedings. April 13-16, 2015. Vancouver, BC, Canada, pp. 44-49.

Whitehead, N.P., Scherer, W.T. and Smith, M.C., 2015. Systems thinking about systems thinking. IEEE Syst J 9: 1117-1128.

Whitmee, S., Haines, A., Beyrer, C., Boltz, F., Capon, A.G., De Souza Dias, B.F., Ezeh, A., Frumkin, H., Gong, P., Head, P., Horton, R., Mace, G.M., Marten, R., Myers, S.S., Nishtar, S., Osofsky, S.A., Pattanayak, S.K., Pongsiri, M.J., Romanelli, C., Soucat, A., Vega, J. and Yach, D., 2015. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation – Lancet commission on planetary health. Lancet 6736: 1-56.

World Health Organisation (WHO), 2009. Systems thinking for health systems strengthening. WHO, Geneva, Switzerland.

Williams, B., 2016. Using systems concepts in evaluation design: a workbook, 1st edition.

Wilson-Grau, R. and Britt, H., 2012. Outcome harvesting. Ford Foundation, Cairo, Egypt. Available at: https://tinyurl.com/y9rpdrjr.

Wolf, M., 2015. Is there really such a thing as 'One Health'? Thinking about a more than human world from the perspective of cultural anthropology. Soc Sci Med 129: 5-11.

Woodward, D., Drager, N., Beaglehole, R. and Lipson, D., 2001. Globalization and health: a framework for analysis and action. Bull World Health Organ 79: 875-881.

Wynne, B., 1996. Misunderstood misunderstandings: social identities and public uptake of science. In: Irwin, A. and Wynne, B. (eds.) Misunderstanding science? The public reconstruction of science and technology. Cambridge University Press, Cambridge, UK, pp. 19-46.

Yukl, G., 2012. Effective leadership behavior : what we know and what questions need more attention. Acad Manag Perspect 26(4): 66-85.

Zinsstag, J., Meisser, A., Schelling, E., Bonfoh, B. and Tanner, M., 2012. From 'two medicines' to 'One Health' and beyond. Onderstepoort J Vet Res 79(2): 492.

Zinsstag, J., Schelling, E., Waltner-Toews, D. and Tanner, M., 2011. From 'one medicine' to 'One Health' and systemic approaches to health and well-being. Prev Vet Med 101: 148-156.